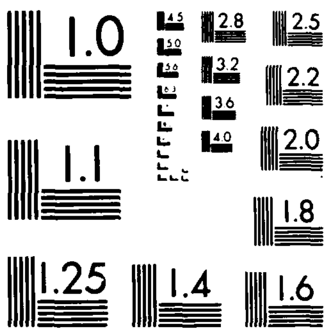
AD-A184 166   FIELD VERIFICATION PROGRAM (AQUATIC DISPOSAL) IMPACT OF   1/2
OPEN-WATER DISPOS (U) SCIENCE APPLICATIONS
INTERNATIONAL CORP NARRAGANSETT RI   J SCOTT ET AL
UNCLASSIFIED   JUL 87 WES/TR/D-87-4   F/G 24/4   NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

US Environmental Protection Agency

AD-A184 166

DTIC FILE COPY (12)

FIELD VERIFICATION PROGRAM
(AQUATIC DISPOSAL)

TECHNICAL REPORT D-87-4

IMPACT OF OPEN-WATER DISPOSAL OF BLACK ROCK HARBOR DREDGED MATERIAL ON BENTHIC RECOLONIZATION AT THE FVP SITE

by

John Scott, Donald Rhoads

Science Applications International Corporation
Narragansett, Rhode Island 02882

Jeffrey Rosen

Computer Sciences Corporation
Narragansett, Rhode Island 02882

Sheldon Pratt
University of Rhode Island
Narragansett, Rhode Island 02882

and

Jack Gentile

Environmental Research Laboratory
US Environmental Protection Agency
Narragansett, Rhode Island 02882

July 1987

Final Report

Approved For Public Release, Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

and

US Environmental Protection Agency
Washington, DC 20460

Monitored by Environmental Laboratory
US Army Engineer Waterways Experiment Station
PO Box 631, Vicksburg, Mississippi 39180-0631

US Army Corps of Engineers

The D-series of reports includes publications of the Environmental Effects of Dredging Programs:

Dredging Operations Technical Support

Long-Term Effects of Dredging Operations

Interagency Field Verification of Methodologies for Evaluating Dredged Material Disposal Alternatives (Field Verification Program)

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A184166

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

- 1a. REPORT SECURITY CLASSIFICATION: Unclassified
- 1b. RESTRICTIVE MARKINGS:
- 2a. SECURITY CLASSIFICATION AUTHORITY:
- 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:
- 3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
- 4. PERFORMING ORGANIZATION REPORT NUMBER(S):
- 5. MONITORING ORGANIZATION REPORT NUMBER(S): Technical Report D-87-4
- 6a. NAME OF PERFORMING ORGANIZATION: See reverse.
- 6b. OFFICE SYMBOL (If applicable):
- 7a. NAME OF MONITORING ORGANIZATION: USAEWES Environmental Laboratory
- 6c. ADDRESS (City, State, and ZIP Code): See reverse.
- 7b. ADDRESS (City, State, and ZIP Code): PO Box 631, Vicksburg, Mississippi 39180-0631
- 8a. NAME OF FUNDING/SPONSORING ORGANIZATION: See reverse.
- 8b. OFFICE SYMBOL (If applicable):
- 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: Field Verification Program (Aquatic Disposal)
- 8c. ADDRESS (City, State, and ZIP Code): Washington, DC 20314-1000 and Washington, DC 20460
- 10. SOURCE OF FUNDING NUMBERS:

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

- 11. TITLE (Include Security Classification): Impact of Open-Water Disposal of Black Rock Harbor Dredged Material on Benthic Recolonization at the FVP Site
- 12. PERSONAL AUTHOR(S): Scott, John; Rhoads, Donald; Rosen, Jeffrey; Pratt, Sheldon; Gentile, Jack
- 13a. TYPE OF REPORT: Final report
- 13b. TIME COVERED: FROM ______ TO ______
- 14. DATE OF REPORT (Year, Month, Day): July 1987
- 15. PAGE COUNT: 127
- 16. SUPPLEMENTARY NOTATION: Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.
- 17. COSATI CODES:

FIELD	GROUP	SUB-GROUP

- 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Benthos (LC), Dredged material (WES), Dredging-Connecticut-Black Rock Harbor (LC), (Continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes the effects of the disposal of dredged Black Rock Harbor (BRH) sediments on the ambient (predisposal) community and the mode and pattern of recolonization at the Field Verification Program (FVP) site. The recolonization process was measured by documenting the rate of recruitment of the FVP site by the dominant species and comparing this with the ambient (reference) community. The parameters used to describe recolonization and convergence with the ambient system are species numbers, abundances of numerically dominant species, degree of infaunalization (successional stage), and depth of biogenic mixing of the bottom sediments (another measure of infaunalization). Both quantitative grab samples and the REMOTS interface camera were used to assess recolonization.

The predisposal sampling indicated that the FVP site was characteristic of the silt-clay facies common to Central Long Island Sound. Extensive surveys to examine the benthic

(Continued)

- 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS
- 21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
- 22a. NAME OF RESPONSIBLE INDIVIDUAL:
- 22b. TELEPHONE (Include Area Code):
- 22c. OFFICE SYMBOL:

DD Form 1473, JUN 86 — Previous editions are obsolete — SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

6a. NAME OF PERFORMING ORGANIZATION (Continued).

Science Applications International Corporation; Computer Sciences Corporation; University of Rhode Island; US Environmental Protection Agency

6c. ADDRESS (Continued).

Narragansett, RI 02882; Narragansett, RI 02882
Kingston, RI 02881; Narragansett, RI 02882

8a. NAME OF FUNDING/SPONSORING ORGANIZATION (Continued).

US Army Corps of Engineers and US Environmental Protection Agency

18. SUBJECT TERMS (Continued).

Dredging-environmental aspects (LC), Marine pollution (LC), Recolonization (LC)

19. ABSTRACT (Continued).

infauna and organism-sediment properties indicated a very homogeneous environment. The patterns of species dominance and organism-sediment indices were also relatively consistent over time. The only differences noted between the disposal site and the reference (REFS) station were mean numbers of individuals per quadrat.

As a result of the disposal operation, a dredged material mound of BRH sediments approximately 1.5 to 2.0 m deep was deposited at the center (CNTR) station. The apron of the mound (depths <10 cm) extended to ca. 200 m in each direction. The species numbers at the 200E station had returned to background levels by December 1983, whereas the recruitment at CNTR was lagging behind what was found at 400E, 1000E, and REFS. By mid-1984, species numbers were similar at CNTR and REFS, with a more diverse assemblage present on the mound.

In the samples that were analyzed, two periods of significant recruitment at CNTR were noted, December 1983 and October 1985. In December 1983, there was significant recruitment of *Mulinia*, *Polydora* (two species), and *Streblospio*, which were not similarly recruited at REFS. In October 1985, recruitment patterns at the two stations were more alike, except for higher abundances of *Mediomastus* and *Tellina* at CNTR and high densities of *Nucula* at REFS, with no significant *Nucula* recruitment to the CNTR station.

REMOTS surveys indicated a significant change in the physical properties of the dredged material disposal mound as compared with the surrounding ambient stations and REFS. A sandy surface was found soon after disposal and continued throughout the survey period. The biological mixing depths (BMD) on the mound (CNTR and other mound stations) increased at a rate of 200 to 400 μm/day, returned to a unimodal condition, and appeared to converge with the BMD at REFS by January 1984. Following this date, however, physical scouring arrested the BMD at the CNTR to levels significantly shallower than those at the REFS station.

The Organism-Sediment Index (OSI) over all of the mound stations developed a bimodal frequency distribution that persisted throughout the study period. In addition, OSI values at the disposal site CNTR were consistently lower than at REFS. The FVP site as a whole showed a successional retrograde in June 1985, in conjunction with the appearance of black (anoxic) sediment at or near the surface in 80 percent of the stations surveyed. Following Hurricane Gloria in early October 1985, all stations sampled (including REFS) experienced a successional retrograde as the result of severe erosion and bottom resuspension. These erosional effects were comparable, in terms of REMOTS parameters, with those measured at the FVP site immediately following the disposal of BRH sediments.

PREFACE

This report describes work performed by the US Environmental Protection Agency (USEPA), Environmental Research Laboratory, Narragansett, Rhode Island (ERLN), as part of the Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives Program (Field Verification Program (FVP)). The FVP was sponsored by the Office, Chief of Engineers (OCE), US Army, and was assigned to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The objective of this interagency program was to field verify existing predictive techniques for evaluating the environmental consequences of dredged material disposal under aquatic, intertidal, and upland conditions. The aquatic portion of the FVP was conducted by ERLN, with the wetland and upland portions being conducted by WES.

Principal investigators for this study and the authors of this report were Drs. John Scott and Donald Rhoads of Science Applications International Corporation, Mr. Jeffrey Rosen of Computer Sciences Corporation, Mr. Sheldon Pratt of the University of Rhode Island, and Dr. Jack Gentile of ERLN. The authors wish to thank Dr. Peter Rogerson for providing sediment chemistry data and the percent Black Rock Harbor calculations, Dr. James Heltshe for statistical advice, and Ms. Lynne Anderson for preparation of the manuscript.

The USEPA Technical Director for the FVP was Dr. John H. Gentile, ERLN; the Technical Coordinators were Dr. Gerald Pesch and Mr. Walter R. Galloway, ERLN.

The study was conducted under the direct WES management of Drs. Thomas M. Dillon and Richard K. Peddicord, Contaminant Mobility and Regulatory Criteria Group (CMRCG), Environmental Laboratory (EL); and under the general management of Dr. Charles R. Lee, Chief, CMRCG; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division; and Dr. John Harrison, Chief, EL. Manager of the Environmental Effects of Dredging Programs was Dr. Robert H. Engler, with Mr. Robert L. Lazor, FVP Coordinator. Dr. Thomas D. Wright, EL, was the WES Technical Coordinator for the FVP reports. This report was edited by Ms. Lee T. Byrne, Information Products Division, Information Technology Laboratory, WES.

The OCE Technical Monitors were Drs. John Hall, Robert J. Pierce, and William L. Klesch. The Water Resources Support Center Technical Monitors were Messrs. Charles W. Hummer and David B. Mathis.

COL Dwayne G. Lee, CE, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Smith, J., Rhoads, D., Rosen, J., Pratt, S., Gentile, J. 1987. "Impact of Open-Water Disposal of Black Rock Harbor Dredged Material on Benthic Recolonization at the FVP Site," Technical Report D-87-4, prepared by the US Environmental Protection Agency, Narragansett, R. I., for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

CONTENTS

LIST OF TABLES

THE IMPACT OF OPEN-WATER DISPOSAL OF BLACK ROCK HARBOR DREDGED MATERIAL ON BENTHIC RECOLONIZATION AT THE FVP SITE

PART I: INTRODUCTION

Background

1. The Marine Protection, Research, and Sanctuaries Act (Public Law 92-532) was passed by Congress in 1972. This law states that it is the policy of the United States to regulate disposal of all types of materials into ocean waters and to prevent or strictly limit disposal of any material that would adversely affect human health, welfare, the marine environment, or ecological systems. The implementation of this law, through issuance of permits as defined in the final regulations and criteria, is shared jointly by the US Environmental Protection Agency (USEPA) and the US Army Corps of Engineers (CE).

2. In 1977, the CE and the USEPA prepared technical guidance for the implementation of the final ocean dumping regulations in the form of a manual entitled "The Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters: Implementation Manual for Section 103 of PL 92-532," (USEPA/CE 1977). This manual specified which test procedures were to be followed in collecting information to be used in making a disposal decision. Among the procedures were those for (a) chemically characterizing the proposed dredged material; (b) determining the acute toxicity of liquid, suspended particulate, and solid phases; (c) estimating the potential contaminant bioaccumulation; and (d) describing the initial mixing during disposal. These methods have been used for determining the suitability of dredged material for open-water disposal. The procedures in this manual represented the technical state of the art at that time and were never intended to remain unchanged or to be applied inflexibly in all situations. The recommended test methods were chosen to provide technical information that was consistent with the criteria specified in the regulations. However, use of the manual in the permit process has identified conceptual and technical limitations with the recommended test methods (Gentile and Scott 1986).

3. To meet this critical need, the Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives Program or the Field Verification Program (FVP) was authorized in 1982. This 6-year program was sponsored by the Office, Chief of Engineers (OCE), and was assigned to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The objective of this interagency program was to field verify existing test methodologies for predicting the environmental consequences of dredged material disposal under aquatic, wetland, and upland conditions. The aquatic portion of the FVP was conducted by the USEPA Environmental Research Laboratory, Narragansett, R. I. (ERLN). The wetland and upland portions, being conducted by WES, are reported in separate documentation.

4. There were three research objectives for the aquatic portion of the program. The first was to demonstrate the applicability of existing test methods to detect and measure the effects of dredged material and to determine the degree of variability and reproducibility inherent in the testing procedure. This laboratory documentation phase of the program is complete, and the results are published in a series of technical reports. This information provides insight into how the various methods function, as well as their sources of variability, their respective and relative sensitivities to the specific dredged material being tested, and the degree of confidence that can be placed on the data derived from the application of the methods.

5. The second objective was to field verify the laboratory responses by measuring the same response under both laboratory and field exposures. A basic and often implicit assumption is that results derived from laboratory test methods are directly applicable in the field. While this assumption is intuitive, there are no supporting data from studies on complex wastes in the marine environment. The study reported herein offers a unique opportunity to test this basic assumption.

6. The third objective was to determine the degree of correlation of tissue residues resulting from bioaccumulation of dredged material contaminants with biological responses from laboratory and field exposure to dredged material. However, this study was not designed to address cause-effect relationships, and the multicontaminant nature of the dredged material precluded any such assumptions.

Project Description

7. The aquatic disposal portion of the FVP was a site- and waste-specific case study that applied the concepts and principles of risk assessment. The disposal site for the FVP is an historical site known as the Central Long Island Sound (CLIS) disposal site (1.8 by 3.7 km), located approximately 15 km southeast of New Haven, Conn. (Figure 1). The sediment at the disposal and reference sites is primarily a silt-clay, with a mean grain size of 0.013 mm. Thermal stratification occurs from April to September, and during this period, bottom salinity is slightly higher than that of the surface. Tidal current flow is the main driving force for the movement of near-bottom water in an east-west direction. The net bottom drift is to the northwest at 0.5 cm/sec. Suspended sediment concentrations average 10 mg/ℓ, with storm-induced values to 30 mg/ℓ at 1 m above the bottom. The baseline community data consist of a homogeneously distributed mature infaunal community dominated by the polychaete *Nephtys incisa* and the bivalve molluscs *Nucula annulata* and *Yoldia limatula*.

8. The FVP disposal site was located in the northeast corner of the CLIS disposal site to minimize contamination from other sources, including preexisting disposal deposits or ongoing disposal activities occurring during the study period. This was necessary to ensure a point source of contamination. The spatial and temporal uniformity of physical, chemical, and biological properties of the disposal site prior to disposal allowed detection of changes in these properties due to the disposal of the dredged material. The stations used to determine the biological effects in this study were selected along the primary axis of current flow and the likely dispersion of deposited materials to represent a gradient of potential exposure for the biota (Figure 2).

9. The spatial scale of this study was near field and was limited to the immediate vicinity of the disposal site. A primary assumption was that the dredged material mound constituted a point source of contamination. The temporal scale for the study was 4 years, which included a year of predisposal data collection to define seasonal patterns in the physical, chemical, and biological variables. The 3 years of postdisposal data collection addressed the objectives of the program and evaluated the long-term impacts of the disposal operation on the surrounding benthic communities.

10. The dredging site was Black Rock Harbor (BRH), located in Bridgeport, Conn., where maintenance dredging provided a channel 46 m wide and 5.2 m deep at mean low water (Figure 1). Approximately 55,000 m^3 of material was dredged during April and May 1983 and disposed in 20 m of water in the northeastern corner of the CLIS disposal site.

11. The dredged material from BRH contained substantial concentrations of both organic and inorganic contaminants (Rogerson, Schimmel, and Hoffman 1985). Polychlorinated biphenyls (PCBs) were present in the dredged material at a concentration of 6,800 ng/g, and polynuclear aromatic hydrocarbons (PAHs) with molecular weights between 166 and 302 were present at concentrations ranging from 1,000 to 12,000 ng/g, respectively. Alkyl homologs of the PAHs were also present in the dredged material at concentrations between 1,000 and 13,000 ng/g. Inorganic contaminants of toxicological importance present in the dredged material included copper (2,380 μg/g), chromium (1,430 μg/g), zinc (1,200 μg/g), lead (380 μg/g), nickel (140 μg/g), cadmium (23 μg/g), and mercury (1.7 μg/g).

Project Scope and Objectives

12. The FVP program objectives were directly focused on addressing specific limitations in the methodologies and interpretive framework of the current regulatory process. Among the program strengths were: (a) a suite of biological endpoints using the same material were developed and evaluated; (b) the biological tests represented different levels of biological organization; (c) the tests were conducted under both laboratory and field exposure conditions; (d) tissue residues were examined concurrently with measures of biological effects; (e) the duration of the study was adequate to evaluate the use of community responses as a benchmark against which other biological responses could be compared; and (f) the project was a site- and waste-specific case study for the application and evaluation of the components of a risk assessment, including the development of methodologies for predicting and measuring field exposures in the water column and benthic compartments. Limitations of this study were: (a) only one dredged material was evaluated, which constrained certain types of comparisons; (b) the size of the study put limits on the extent to which any given objective could be examined; and (c) the field exposures have not been determined. The latter is particularly

important because the laboratory-field comparisons and the risk-assessment process both require accurate predictions of environmental exposures.

13. This report describes the results of field investigations conducted as part of the aquatic portion of the FVP to examine the benthic community at the site and the reestablishment of that community following the disposal of BRH sediments. This study was not designed to determine the effects of dredged material on benthic communities but to describe the recolonization process for a disturbed habitat. The specific objectives of this work were threefold. The first objective was to describe the ambient and control community as a basis for comparison with the impacted site. The second objective was to examine the spatial extent of recolonization effects along an exposure gradient for the 6 months following disposal. The third and final objective was to describe the recolonization process over the long term (2.5 years) at two stations, the mound apex and the control site. These three objectives are addressed in this report through the use of two independent benthic-assessment techniques, quantitative benthic sampling and the REMOTS interface camera.

Central Long Island Sound Communities

14. The benthic macrofaunae have long been considered as excellent indicators of environmental change because of their sessile nature and intimate association with near-bottom sediments and particulate-associated contaminants (Pearson and Rosenberg 1978). Changes in the numbers and types of species, as a result of an environmental perturbation, integrate a wide range of effects on the biological hierarchy from the individual to the population, to the interactions of populations that are manifested as the community structure. Populations of organisms may respond to perturbations either positively or negatively, or not at all; however, similar types of benthic species tend to respond in a similar fashion. For example, benthic deposit feeders may increase in numbers as a result of the deposition of nutrient-enriched sediments, whereas suspension feeders, as a whole, may decrease in numbers because of a high sediment load. An understanding of how different populations respond functionally as groups provides insight into what types of impacts are occurring.

15. The earliest quantitative benthic studies in CLIS were conducted by Sanders (1956), who initially described a community of fine-textured sediment

that was dominated by polychaetes and bivalve molluscs. This community consisted primarily of selective and nonselective deposit feeders. This community, known as the *Nephtys-Nucula-Yoldia* assemblage, is characteristic of fine-grained habitats throughout southern New England. Two other species common to this community are the bivalve *Mulinia lateralis* and the polychaete *Mediomastus ambiseta*.

16. McCall (1977) examined the recolonization patterns of the benthic community in shallow water at a site north of CLIS. He observed that, when habitats were defaunated, they were quickly recolonized by small, short-lived opportunistic macroinfaunae, such as the polychaetes *Streblospio* and *Capitella* and the amphipod *Ampelisca*. In the absence of continued disturbance through time, these opportunistic macroinfaunae were gradually succeeded by larger, longer lived equilibrium species like the polychaete *Nephtys* and the bivalve *Yoldia*. Samples of defaunated fine-grained sediment placed on the bottom of CLIS yielded opportunistic communities within 10 days, and within 3 months, the community was similar to that of the surrounding bottom with respect to the number and diversity of species (McCall 1977). Within a year, the colonized sediment community was similar to that of the surrounding bottom. Subsequent studies by Rhoads and Germano (1982) and Germano (1983) have verified McCall's hypothesis, and they have incorporated his data into successional models describing the colonizing pattern for the benthos.

17. With the advent of dredged material disposal at the CLIS site in the early 1970s, quantitative benthic sampling was conducted by the CE New England Division (NED) (Rhoads 1973, 1974) and the NED Disposal Area Monitoring System (DAMOS) (Brooks 1983). The topographic relief and the variable sediment texture of the various disposal mounds in CLIS have led to the development of communities characteristic of coarse-grained habitats dominated by the polychaetes *Spiophanes* and *Ampharete* and the suspension-feeding bivalves *Tellina* and *Ensis*. These data indicate that, if coarser textured sediments are available, a different community type will develop.

PART II: MATERIALS AND METHODS

Predisposal and Postdisposal Sampling Design

18. The physical, chemical, and biological characteristics at the FVP site were assessed during the year prior to disposal. Stations were sampled on a quarterly basis, in May, August, and December 1982 and in March 1983. The intent of the predisposal sampling was to assess both the large- and small-scale variability of the site and then to establish stations for the remaining predisposal and postdisposal periods. In May and August 1982, 42 stations were sampled on an orthogonal grid using a 0.1-m^2 Smith-MacIntyre grab sampler and the Remote Ecological Monitoring of the Seafloor System (REMOTS) (Figure 3). Large-scale variability was established using these stations, whereas small-scale variability was assessed by intensively sampling a few selected stations with the grab sampler.

19. The final selection of stations for the community studies was made to reflect a gradient of exposure to BRH sediments. As such, the highest exposure would be expected at the center of the disposal site and the lowest exposure at a reference station where no BRH sediments would be expected to be present. A transect of intermediate stations along the east-west axis of tidal currents at the FVP site was established. Based on chemical analyses of samples taken at these stations, simulations of the field exposures could then be done in the laboratory as a dose series analogous to that used for dose-response experiments.

20. On this basis, five major stations were selected for biological sampling: Center, 200E, 400E, 1000E, and South Reference. The Center station (CNTR), located at the center of the disposal mound, represents the highest predicted exposure to BRH material. The South Reference (REFS) station, located 3 km to the south-southwest, was chosen because there was little likelihood of contaminated BRH sediment reaching that site and there exists historical information from that site due to its previous use as a DAMOS control site (Morton 1982). Stations 200E (200 m east) and 400E (400 m east) were chosen to bracket the predicted edge of the mound. These locations were chosen based on experience from previous disposal operations and verified through postdisposal observations. The 1000E station was selected in addition to the REFS station. It is closer to the experimental site, is at the same

water depth, and is along the axis of maximum ebb tidal flow from the center of the mound. The community at the 1000E station might, therefore, be affected by resuspension and tidal flux of BRH material coming off the mound.

21. The December 1982 and March 1983 predisposal grab samples were collected at the above five stations. In March, a reconnaissance survey was conducted at 15 stations in a north-south, east-west grid that was based on the results of the August 1982 survey using REMOTS. Diver observations and reconnaissance surveys conducted just after disposal by REMOTS confirmed that the five benthic grab stations represented the exposure gradient upon which their original selection was based, and postdisposal sampling continued at these locations. Following the completion of the disposal operation in May 1983, five replicate Smith-MacIntyre grabs were taken at each of the five stations in June, July, September, and December 1983. To examine the long-term recolonization of the mound, three replicate grab samples were collected at the CNTR and REFS stations in June 1984, June 1985, and October 1985, following the passage of Hurricane Gloria. The areal dispersion limits of BRH disposed materials were mapped by intensive REMOTS mapping following disposal in June 1983. Over 90 percent of the area affected by the disposal operation consisted of a layer of BRH sediment ≤20 cm thick. The REMOTS survey was able to map the edge of the deposit to a resolution of about 1 mm thick. Stations were laid out relative to the location of the central mound apex and outer perimeter of the BRH deposit. REMOTS surveys were conducted at the FVP site in June, July, and August 1983 and in January 1984. Long-term monitoring consisted of quarterly surveys through October 1985. The number of REMOTS sampling stations and frequency of sampling are summarized in Table 1.

Sampling Methods

Smith-MacIntyre grab samples

22. Sediment samples were taken for infaunal analysis with a 0.1-m^2 Smith-MacIntyre grab sampler and sieved on board through a 0.5-mm mesh screen. The retained organisms were preserved in 10-percent buffered formalin with rose bengal to stain living tissue. Prior to sieving, while the sample was still in the grab, a 7-cm-diam by 15-cm-long core was removed and preserved intact in 10-percent buffered formalin with rose bengal. This core was

Table 1

Postdisposal REMOTS Surveys and Number of Stations

Sampled at the FVP Site

Date	Number of Station
Jun 1983	33
Jul 1983	21
Aug 1983	21
Jan 1984	20
Mar 1984	22
Jun 1984	21
Sep 1984	57
Dec 1984	21
Mar 1985	21
Jun 1985	21
Oct 1985	21

subsequently archived to be used as a subsample for organism enumeration or to examine organisms retained on finer mesh screens.

23. Samples were preserved with worm tubes, clay lumps, and mud balls intact, to reduce damage to organisms before they were hardened by preservation. Samples were then washed with fresh water and separated into >1-mm and 1- to 0.5-mm fractions. Sieving was carried out in a container of water so that particles could be suspended, allowing them to pass freely through the sieve pores. Large pebbles, shells, and animal tubes were removed from the coarse fraction at this stage. The tubes of ceriantnid anemones, to which small polychaetes and oligochaetes adhere, were set aside for microscopic examination. The remaining coarse fraction was placed in glass trays with a white background, and the organisms were removed and then sorted.

24. Fine material was further separated into relatively uniform "light" and "heavy" fractions. This uniformity made sorting easier and was necessary if samples were to be split. Repeated suspension in a 3-ℓ pitcher and decantation separated polychaetes, crustaceans, and organic detritus from molluscs, shell residue, and polychaete fecal pellets.

25. Samples that appeared to have over 1,000 individuals of the polychaete *Mediomastus ambiseta* (maximum densities were up to 8,000/sample) were split prior to sampling. The light fraction was suspended in a rotary plankton splitter and divided by one-half, one-fourth, or one-eighth. If the heavy fraction contained many fecal pellets, it was placed in a low-powered sonic bath for 5 to 10 min and then rewashed.

26. All fine fractions and clumps of organic detritus and anemone tubes from coarse fractions were examined with binocular microscopes, and the organisms were removed. These were identified, counted, and preserved in 70-percent alcohol. *Yoldia limatula* (bivalve), *Nephtys incisa* (polychaete), and *Ampelisca* sp. (crustacean) were labeled by station and date and archived for further analysis. The remaining organisms were preserved and archived. The sieve residue was described, and the volume was estimated and preserved for future reference.

27. Key taxonomic references were Gossner (1971) for all groups, Fauvel (1927) and Pettibone (1963) for polychaetes, Abbott (1974) for molluscs, and Bousfield (1973) for amphipods. Blake (1971) was consulted regarding polychaetes of the genus *Polydora*.

REMOTS samples

28. REMOTS images were taken using a Benthos Model 3731 Sediment-Profile Camera (Benthos Inc., North Falmouth, Mass.) (Figure 4). The camera consists of a wedge-shaped prism with a Plexiglas faceplate; light is provided by an internal strobe. The back of the prism has a mirror mounted at a 45-deg angle to reflect the profile of the sediment-water interface up to the camera, which is mounted horizontally on the top of the prism. The prism is filled with optically clear water, and because the object to be photographed is directly against the faceplate, turbidity of the ambient seawater is never a limiting factor. The camera prism is mounted on an assembly that can be moved up and down by producing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. The support frame hits the bottom first, leaving the area to be photographed directly under the prism undisturbed. Once the camera's frame touches the bottom, slack on the winch wire allows the prism to vertically cut the seafloor. The rate of fall of the optical prism into the bottom is controlled by an adjustable "passive" hydraulic piston. This allows the optical prism to enter the bottom at approximately 6 cm/sec. This slow fall rate ensures that

the descending prism does not wash or otherwise resuspend the sediment-water interface by a "bow-wave." The bottom edge of the optical prism (shaped like an inverted periscope) consists of a blade that cuts a vertical profile of the bottom. The prism is driven several centimetres into the seafloor by the weight of the assembly. The camera trigger is tripped on impact with the bottom, activating a 13-sec time delay on the shutter release; this gives the prism a chance to obtain maximum penetration before a photo is taken. As the camera is raised to a height of about 2 m from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate; the film is automatically advanced by a motor drive, the strobes are recharged, and the camera is ready to be lowered for a replicate image. Specific measurement techniques for the REMOTS parameters are presented in the following paragraphs:

29. Sediment-type determination. The sediment grain-size major mode and range are visually estimated from the photographs by overlaying a grain-size comparator that is at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth-size classes (equal to or less than coarse silt up to granule and larger sizes) through the REMOTS camera. The seven grain-size classes on this comparator are: <4 phi, 4 to 3 phi, 3 to 2 phi, 2 to 1 phi, 1 to 0 phi, 0 to -1 phi, and $\leq$ phi. The lower limit of optical resolution of the photographic system is about 52 μ, allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing REMOTS grain-size major mode estimates with grain-size statistics determined from laboratory sieve analyses.

30. Surface boundary roughness. Surface boundary roughness is determined by measuring the vertical distance (parallel to the film border) between the highest and lowest points of the sediment-water interface. In addition, the physical or biogenic origin of this small-scale topographic relief is indicated when it is evident. In sandy sediments, boundary roughness can be a measure of sand ripple height. On silt-clay bottoms, boundary roughness values often reflect biogenic features such as fecal mounds or surface burrows. Boundary roughness class limits (centimetres) used in subsequent frequency distributions are shown in Table 2.

31. Mud clasts. When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging),

Table 2

Class Limits for REMOTs Boundary Roughness Values

Boundary Roughness Class	Class Limits cm
1	0.00-0.20
2	0.20-0.41
3	0.42-0.62
4	0.63-0.83
5	0.84-1.04
6	1.05-1.25
7	1.26-1.46
8	1.47-1.65
9	1.66-1.80
10	1.81-2.01
11	>2.02

intact clumps of sediment are often evident on the seafloor. These mud clasts can be detected at the sediment-water interface in REMOTs images. During analysis, the number of clasts is counted, the diameter of a typical clast is measured, and their surface oxidation state is assessed. Der 'ing on their place of origin and the depth of disturbance of the sediment columr clasts can be reduced (dark) or oxidized (light). Also, once at the sediment-water interface, these sediment clumps are subject to botton r oxygen levels and bottom currents. Based on laboratory microcosm observatio of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6 to 12 hr (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, angular versus rounded, are also considered. Mud clasts may be moved about and broken by bottom currents and animals (macro- or meiofauna) (Germano 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and appearance of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

32. Biogenic mixing depth (BMD). Prior descriptions of REMOTS data have involved the measurement of the mean depth of the apparent Redox Potential Discontinuity (RPD). The RPD is defined as the level or depth within the bottom sediments where pore-water Eh equals zero. This chemical interface can be measured only by a microelectrode. The REMOTS sediment-water profile camera does not measure this gradient, but rather it images the distribution of near-surface high-reflectance sediment containing particles coated with ferric hydroxide and an underlying low-reflectance sediment containing iron monosulphide or pyrite. The area of high reflectance is measured in sediment profile images through a process called density slicing. A computer image-analysis system is used to define the reflectance of interest by 256 grey-scale density slicing. A narrow grey-scale window width is used to define the upper and lower limits of the high-reflectance layer. This narrowly defined area of the image is then digitized, scaled, and measured. The area of high-reflectance sediment is then divided by the width of the image to give average thickness of the layer. Although this reflectance stratigraphy is related to Eh gradients, oxidized sediment (i.e., ferric-hydroxide grain coatings) can exist for long periods of time in negative Eh pore water that is completely devoid of free molecular oxygen. This "disequilibrium" phenomenon can come about by particles being oxidized at the sediment-water interface or in burrow linings at depth. These oxidized particles may be subsequently advected downward, or laterally, into negative Eh environments. Reduction of ferric hydroxide coatings may take a long time, and, in some cases, this metastable oxidation state may persist over geological time scales (e.g., redbeds intercalated between black shales). This "disequilibrium" phenomenon was used to advantage in the postdisposal FVP REMOTS survey. BRH (black mud) was dumped on top of high-reflectance sediment characteristic of the pristine disposal area. The contact between the base of this black mud and the underlying ferric-hydroxide coated sediment was easily seen in profile images. This optical contact was used for over 1 year as a datum for measuring the thickness of disposed material.

33. For these reasons, reference to the boundary between high- and low-reflectance sediments as the apparent RPD has been abandoned. The thickness of the high-reflectance sediment is determined by the interaction of two rates: the rate of downward transport of particles and oxygenated pore water and the rate of consumption of oxygen and reduction of the coatings at depth.

For most sediments, the downward mixing is related to the BMD (bioturbation depth). This depth is important to map, as it reflects the degree of infaunalization that, in turn, can be related to environmental stress and the disturbance history of the benthic habitat.

34. Those cases in which the above relationships do not hold are associated with highly stressed or disturbed habitats where no bioturbating metazoa are present. If high-reflectance sediment is present, its thickness is related to Fickian diffusion of molecular oxygen. These cases are relatively easy to identify as the thickness of the high-reflectance sediment is on the order of 1 to 2 mm and the layer is laterally uniform in thickness. When organisms are responsible for advection, the thickness of the high-reflectance sediment is laterally variable and is related to the density and spacing of the organisms. In highly reducing sediments, the BMD may be underestimated because the reducing ability of the sediment exceeds the rate of supply of oxidized particles. In other words, particle coatings are reduced before they arrive at the base of the mixing zone. This case is recognized by the extension of active tubes or imaged worm biomass well below the high-reflectance layer. Finally, high rates of physical mixing can produce thick surface layers of high-reflectance sediment that may be unrelated to biogenic activity. These may be recognized by the presence of surface bed forms and a relatively uniform lateral thickness of the high-reflectance surface sediment.

35. Sedimentary methane. At extreme levels of organic loading, pore water sulfate is depleted, and methanogenesis occurs. This process is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernible because of their irregular, generally circular form and glassy texture (due to the reflection of the strobe off the gas). If present, the number and the total areal coverage of all methane pockets are measured.

36. Infaunal succession. The mapping of successional stages is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest . . . , our

definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982, Rhoads and Germano 1982).

37. The term "disturbance" is used here to define natural processes, such a seafloor erosion, changes in seafloor chemistry, foraging disturbances that cause major reorganization of the resident benthos, or anthropogenic impacts, such as dredged material or sewage sludge dumping, thermal effluents from power plants, pollution impacts from industrial discharge, etc. An important aspect of using this successional approach to interpret benthic monitoring results is relating organism-sediment relationships to the dynamic aspects of end-member seres. This involves deducing dynamics from structure, a technique pioneered by Johnson (1972) for marine soft-bottom habitats. The application of an inverse-methods approach to benthic monitoring requires the in situ measurements of salient structural features of the organism-sediment relationships measured through REMOTS technology.

38. Pioneering assemblages (Stage I assemblages) consist of dense aggregations of near-surface, tube-dwelling polychaetes. These functional types are usually associated with a shallow, biogenic mixing depth, particularly in the earliest stages of colonization, (e.g., Spionidae, Capitelliade, Owenidae, and Oligochaeta). Stage III taxa, in turn, represent high-order successional stages typically found in low-disturbance regimes. These invertebrates are infaunal, and many feed at depth in a head-down orientation, e.g., Maldanidae and protobranch bivalves. The localized feeding activity results in distinctive excavations, called feeding voids. Diagnostic features of these feeding structures include: a generally semicircular shape with a flat bottom and arched roof and a distinct granulometric change in the sediment particles overlying the floor of the structure. This relatively coarse-grained material represents particles rejected by the head-down deposit-feeder. These deep-dwelling infaunal taxa preferentially process the finer sediment particles. Other subsurface structures, e.g., burrows or methane gas bubbles, do not exhibit these characteristics. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment and causing the high-reflectance horizon (ferric-hydroxide coated particles) to be located several centimetres below the sediment-water interface. Polychaetes of the family Maldanidae are particularly important in producing deep (to 20 cm) subsurface feeding voids.

39. These end-member stages (Stages I and III) are easily recognized in REMOTS images by the presence of dense assemblages of near-surface polychaetes and/or the presence of subsurface feeding voids. Both types of assemblages may be present in the same image. Stage II taxa are commonly represented by tubicolous amphipods and opportunistic bivalves (e.g., *Mulinea lateralis* and Tellinids).

40. Organism-Sediment Index. A multiparameter REMOTS Organism-Sediment Index (OSI) has been constructed to characterize habitat quality. Habitat quality is defined relative to the two end-member standards discussed previously. The lowest value, -10, is given to those bottoms that have low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment (Rhoads and Germano 1982). At the other end of the scale, an aerobic bottom with a deeply depressed BMD, evidence of a Stage III mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have an OSI value of +11 (Table 3).

Sediment sampling methods

41. Intact sediment cores were collected from the five FVP stations at each postdisposal sampling date for chemical and grain-size analysis. Sediment cores that were 7 cm in diameter were collected from the Smith-MacIntyre grab sampler and stored intact on ice for transport to the laboratory. The cores were then frozen for later analysis. Predisposal samples were collected by surface sediment scoops and stored in glass jars.

Grain-size analysis

42. Cores were removed from the freezer and thawed to allow slicing. The top 2 cm of each core was cut and homogenized in a polyethylene bottle. A sample size of 5 to 15 g wet weight was used for each analysis and was soaked in a dispersant (2.55-g/ℓ solution of sodium carbonate and sodium tripolyphosphate) until no flocculation existed. The sand fraction was determined by wet sieving through a 63-μ mesh screen, drying at 100° C for 25 hr and weighing. The remaining fine fraction was then analyzed by the pipette method after Folk (1980).

43. Sediment was characterized into four classes by percent weight, according to the following grain sizes:

Sand: Less than or equal to 4 phi

Coarse Silt: Greater than 4 phi but less than 6 phi

Table 3

Parameters and Their Index Values Used To Calculate the REMOTS OSI

Mean BMD Depth, cm	Index Value
0	0
> 0 - 0.75	1
0.76 - 1.50	2
1.51 - 2.25	3
2.26 - 3.00	4
3.01 - 3.75	5
> 3.75	6

Chemical Parameters	Index Value
Methane present	-2
No/low dissolved oxygen	-4

Successional Stage (Primary Succession)	Index Value
Azoic	-4
Stage I	1
Stage I-II	2
Stage II	3
Stage II-III	4
Stage III	5

Successional Stage (Secondary Succession)	Index Value
Stage I on a Stage III	5
Stage II on a Stage III	5

REMOTS OSI = total of all subset indices

Range: -10 to +11

Medium Silt: Greater than or equal to 6 phi but less than 7 phi
Clay: Greater than or equal to 8 phi

Chemical Methods

44. The analytical methods used in this study are presented here in summary form. More detailed descriptions of the analytical methods are available in Lake, Hoffman, and Schimmel (1985). Most of these methods represent extensive modifications of USEPA standard methods developed for freshwater and wastewater samples. It was necessary to modify these methods in order to analyze the types of matrices in this study. These methods were intercalibrated to ensure the quality of the data.

Organic sample preparation and analysis

45. Samples of sediment were extracted by multiple additions of increasingly less polar organic solvents using a tissue homogenizer. These mixtures were separated by centrifugation between additions, polar solvents were removed by partitioning against water, and the extracts were desulfured with activated copper powder when required. The extracts were then passed through a precolumn containing activated silica gel. All of the above extracts were subjected to column chromatography on deactivated silica gel to separate analytical fractions and were volume reduced carefully prior to analysis.

46. Electron capture gas chromatographic analysis for PCBs was conducted on a Hewlet-Packard 5840 gas chromatograph equipped with a 30-m DB-5 fused silica column. Samples were quantified against an Aroclor 1254 standard because the distribution of PCB congeners in the dredged material closely matched that distribution, as did the distribution in organisms at steady state.

47. Gas chromatograph/mass spectrometric (GC/MS) analyses were conducted with a Finnigan Model 4500, also equipped with a 30-, DB-5 fused silica capillary column. The mass spectrometer was operated through a standard Incos data system and was tuned at all times to meet USEPA quality assurance specifications.

48. All instruments were calibrated daily with the appropriate standards. The concentrations of the standards used were chosen to approximate those of the contaminants of interest, and periodic linearity checks were made

to ensure the proper performance of each system. When standards were not available, response factors were calculated using mean responses of comparable standards. Blanks were carried through the procedure with each set of samples, and reference tissue homogenate was analyzed with every 12 to 15 samples.

Inorganic sample preparation and analysis

49. Sediment was prepared for inorganic analysis by elution at room temperature with 2N HNO_3. The samples were filtered through Whatman #2 filter paper.

50. All flame atomization (FA) atomic absorption (AA) was conducted with a Perkin-Elmer (Model 5000) atomic absorption spectrophotometer. All heated graphite atomization (HGA) atomic absorption determinations were conducted with Perkin-Elmer Model 500 or 2100 HGA units coupled to Perkin-Elmer Model 5000 or 603 atomic absorption instruments, respectively. The Model 5000 AA was retrofitted with a Zeeman HGA background correction unit, and the Model 603 was equipped with a D_2 arc background correction system.

51. The FA-AA and HGA-AA instrument operating conditions were similar to those described in "Methods for the Chemical Analysis of Water and Wastes" (USEPA 1979) and those in the manufacturer's reference manuals. The AA instruments were calibrated each time samples were analyzed for a given element. Sample extracts were analyzed a minimum of twice to determine single reproducibility. Quality assurance checks, conducted after every 15 samples, were analyzed by the method of standard addition and by analyzing one procedural blank.

Data Analysis

Smith-MacIntyre grab sample analysis

52. All data storage and manipulation for the species counts were done using the DATMAN data management system (Bass 1980). A data file with columns for the coarse- and fine-sieve fractions for each species found in a sample quadrat was set up. Each line in the data file was identified by the sample station, date, and replicate number. The surface area of the analyzed sample was also recorded with the raw data. The totals were calculated by adding the number found in the coarse fraction and the number found in the fine fraction.

The station, date, replicate number, and the surface area of the core were also retained in the data file of the totals.

53. On-line summaries for the community data included three data files that contained the mean of the total for each species, the standard deviation of that mean value, and the number of observations included in the calculation of the mean and standard deviation. The data in these summary data files were corrected for the removal of core subsamples that were preserved intact for later analysis. The quadrat size of a Smith-MacIntyre grab is 1,000 cm^2. The core removed 50.3 cm^2 from the surface area of the sample quadrants. If subsamples were not removed from the sample quadrats, then the value 1,000 cm^2 was entered for the sample surface area. Prior to taking means, all values were corrected to 0.1 m^2 (1,000 cm^2) as follows:

$$\text{Corrected species count} = \frac{1{,}000 * (\text{Uncorrected species count})}{\text{Surface area of the sample quadrat}}$$

In this study, this correction factor increased the value of each species found by only 5 percent for those quadrats that had subsamples removed. Presence-absence, mean number of species per quadrat, and total number of species found at a station were unaffected by this correction factor.

54. A separate data file was set up containing a summary of community parameters. Specifically, for each station and date sampled, the mean number of individuals per quadrat, the mean number of species per quadrat, and the total number of species found over all quadrats were calculated.

55. In addition to the community parameters discussed previously, analyses were performed on selected individual species. The selection of these species was based on their dominance in both the predisposal and post-disposal samples and their functional importance to the community.

56. Spatial heterogeneity and homogeneity were analyzed by calculating between stations and within station variances for the predisposal samples. Variance components were estimated using the procedure VARCOMP in SAS (SAS 1985). Detectable differences in species abundances were determined using the sample size determination modified from that given by Snedecor and Cochran (1980) to read:

$$\delta = \sqrt{\frac{\left(Z_\alpha + Z_\beta\right)^2 2S^2}{n}} \quad (1)$$

where

δ = the detectable difference

$Z_\alpha + Z_\beta$ = factor that controls the power of the test and the type I error. Here this value is fixed for a two-sided test with a = 0.05 and P' = 0.80 at the value 7.9.

S^2 = the within station variance. Multiplied by 2 to account for testing differences between two stations using pooled estimates of variances.

n = the sample size = 5

57. Detectable differences between stations are reported as the absolute difference in abundances for a given species (as a percent of the overall mean) that must be realized in order to detect differences with alpha = 0.05 for a given sample date. Changes in species abundance are represented as the percent of overall mean.

58. Differences in species abundance between stations on a given date were determined using the General Linear Models procedure in SAS (1985), and specific differences were determined using Duncan's multiple range test. All values for the individual species were transformed where appropriate to stabilize the variances. The number of species per quadrat and the total number of species found over all quadrats were not transformed prior to the analyses of variance. A log transformation was performed on the number of individuals per quadrat prior to conducting the analysis of variance.

59. The individual species included in the detailed analyses of the benthic community were those used for cluster analysis. The values used to perform this analysis were means of $\log_{10}$ transformed abundances for each date and station.

60. The OSI and the BMD were both calculated using rank transformed data (Conover and Inman 1981). Cluster analysis for the community data was done by standardizing the mean number of species per quadrat, the mean number of individuals per quadrat, and the OSI and the BMD by setting the mean equal to zero and the variance equal to one.

61. All analyses of variance were conducted using the general linear models procedure (PROC GLM) (SAS 1985). Differences between CNTR and REFS were determined using an F test with an $\alpha = 0.05$. Cluster analyses were conducted with the procedure CLUSTER (SAS 1985) using the centroid method.

REMOTS analysis

62. Most of the REMOTS biological parameters are measured directly from the film negatives using a video digitizer and computer image-analysis system (LMS II, Measuronics, Inc.). Negatives are used instead of positive prints to avoid changes in image density that can accompany the printing of a positive image. The computer system can discriminate up to 256 different gray scales, so subtle features can be accurately digitized and measured. Proprietary software allows the measurement and storage of data on 22 different variables for each REMOTS image obtained. Before all measurements from each REMOTS image are stored on disk, a summary display is made on the screen so that the operator can verify if the values stored in memory for each variable are within the expected range. If anomolous values are detected, software options allow remeasurement before storage on disk. All computer data disks are backed up by redundant copies at the end of each analytical day. All data stored on disks are printed out on data sheets for editing by the principal investigator and as a hard-copy backup for each REMOTS. All data sheets were edited and verified by a senior-level scientist before being approved for final data synthesis, statistical analyses, and interpretation.

63. REMOTS data for most parameters are presented in the graphical format of frequency distributions. Differences between sample sets are expressed as differences in the frequency distribution and its major mode.

64. Specific comparisons of OSI and BMD data collected at the CNTR and REFS stations for all sample dates were made using analysis of variance as described previously.

Chemistry analysis

65. Contaminant analysis. As stated previously, PCBs were quantified as Aroclor 1254 because the sample patterns closely resembled that profile. This allowed a convenient way of reporting these data without treating the voluminous data that would have resulted from measuring some 55 congener peaks by electron capture detector. Likewise, a method was sought to summarize the data on the 35 individual PAH parent and alkyl homolog compounds and groups of compounds measured in this study. Since the distribution of PAHs differed greatly in both quantity and quality between Long Island Sound and the BRH dredged material, statistics were sought that would retain significant quantitative and qualitative information. The quantitative statistic chosen was the simple SUM of all measured PAHs.

66. Contaminant selection. Chemical analyses performed in this study characterized the organic and inorganic constituents in the dredged material, provided information on the laboratory and field exposure environments, provided insight into the processes governing contaminant movement within and between environmental compartments, and determined which contaminants were accumulated by organisms. In determining the acceptability of dredged material for ocean disposal, a variety of evaluatory criteria are applied. These include bulk sediment chemistry, toxicity, and bioaccumulation. In this study, bioavailability was determined by examining the types and distributions of contaminants that bioaccumulated in laboratory studies (Rogerson, Schimmel, and Hoffman 1985). Based upon the contaminant profile for the dredged material and residue data, the contaminants selected for detailed analyses throughout the study included PCBs, PAHs, the pesticide ethylan, and eight metals.

67. Sediment BRH estimates. The proportions of BRH dredged material in the surficial sediments at each station and date were estimated by comparing the concentrations of selected contaminants measured in the top 2-cm layer of sediment cores collected, postdisposal, at the FVP site. These field concentrations were compared with the barrel concentrations to determine a percentage as follows:

$$\text{Percentage BRH Sediment} = \frac{(C-REF)}{(BRH-REF)} \quad 100 \qquad (2)$$

where

C = concentration of contaminant in the dredged sediment

REF = concentration of contaminant in reference (REF) sediment

BRH = concentration of contaminant in BRH sediment (barrel)

The percentage of BRH sediment values were calculated for each station and date using 11 different contaminants.

PART III: RESULTS

Predisposal Characterization

Physical properties

68. Grain-size analysis. The particle-size distribution in the predisposal area was spatially uniform, with over 90 percent (by weight) of the particles falling within the coarse-silt or finer classes (<62 μm or >4 phi). The grain-size distribution at the predisposal site in March 1983, measured by sieving and pipette analysis, was the same for the CNTR, 1000E, and REFS stations (Figure 5). REMOTS images from surveys conducted predisposal in August 1982 and March 1983 also indicated that the major modal grain size was within the >4-phi class for all stations sampled.

69. The REMOTS images showed the upper few millimetres of surface sediment to consist of sand-size organic-mineral aggregates. These aggregates consisted of fecal pellets and broken fragments of an otherwise cohesive silt-clay associated with intensive and extensive bioturbation of this facies by the resident infauna. This surface layer of sand-size aggregates is usually disturbed during sampling or otherwise destroyed during laboratory grain-size analysis. For this reason, the presence of this surface "sand" layer is not recorded in the weight-size-frequency diagrams of Figure 5.

70. Boundary roughness. Small-scale boundary roughness frequency histograms are shown in Figure 6 from both the August 1982 and March 1983 predisposal REMOTS surveys. The major modal roughness class in both cases is 3 (0.31 to 0.62 cm). The sample means (±SD) were, respectively, 0.71 ± 0.24 cm in August and 0.83 ± 0.45 cm in March. These two distributions were significantly different at the $P = 0.05$ level (Student's t-test). The origin of this small-scale roughness in August can be qualitatively related to the presence of biogenic relief at the sediment surface produced by the presence of feeding mounds, piles of fecal pellets, burrow openings, and feeding depressions. The enhanced March 1983 roughness data can be qualitatively related to physical scouring of the bottom as recognized by imaged depressions formed by "plucking" erosion and the appearance of mud clasts at the sediment surface. Only 18 percent of the August replicates showed such features, whereas 68 percent of the March images showed erosional microtopography.

Biological Properties

71. Number of species and individuals. A list of all species found at the FVP site throughout the course of this study is contained in Appendix A, Table A1. A complete tabulation of species abundances for all sample dates may be obtained from the Environmental Research Laboratory in Narragansett, R. I. The mean densities of the dominant species during the predisposal and postdisposal periods are listed in Appendix B.

72. Prior to the disposal of BRH dredged material, 82 species of benthic invertebrates were identified within the study area. The numbers of species and number of individuals for the four predisposal sample dates are shown in Table 4. The mean number of species varied from a low of 24 in August 1982 to between 32 and 33 in December 1982 and March 1983. There were no statistically significant station differences in species number for any sample date. Similarly, the mean density varied from a low in August to values seven and six times higher in December and March, respectively. Significant station differences were found in December, with all of the disposal site mean densities higher than the REFS station mean number of individuals (3,567/0.1 m^2) by at least a factor of two (Table 4).

73. Dominant species. Any species that was one of the 10 most abundant organisms in each of the sampling dates is listed along with its rank in Table 5. The species are ordered by their total rank sum. The seasonal consistency in species dominance is shown here, in that only 13 species make up this list.

74. This community was dominated by polychaete and bivalve species that are typical of fine, soft-bottom habitats and is represented by the *Nephtys-Nucula-Yoldia* community. The deposit-feeding bivalve *Nucula annulata*, the most abundant species, exhibited relatively constant abundances over time. Those species populations that exhibited large increases in abundance in December 1982 and March 1983 were the bivalves *Mulinia* and *Yoldia*, the polychaete *Mediomastus*, and the oligochaetes. *Nephtys* abundances gradually decreased from May 1982 to March 1983. Predisposal abundances of the dominant species at the five FVP stations are presented in Figures 14 through 21 in conjunction with the results of the postdisposal characterization.

75. Analyses of variance for individual species were done on the predisposal data to determine differences between stations for each sampling date. *Nucula annulata* and *Nephtys incisa* exhibited between-station

Table 4

Summary of Mean Density and Richness Data for the Predisposal Community

Date	Mean Number of Individuals per 0.1 m^2*	Mean Number of Species per 0.2 m^2*
May 82	1,040	28
Aug 82	943	24
Dec 82	7,168 ** 8,068 †	33
Mar 83	6,283	32

* Mean value over all stations for each date.
** Mean density with REFS samples included.
† Mean density without REFS samples included.

differences only for the May 1982 sample date. Like the differences described earlier for the total number of species found over all sample quadrats, these differences appear to be an artifact of the preliminary sampling plan used on the May 1982 cruise. The differences showed no pattern and were closely related to the number of samples taken at the stations. With the exception of the differences observed for the May sampling, all stations on subsequent sampling dates were statistically the same.

76. The number of species was similar for all stations on all dates with the exception of low abundances recorded at the REFS station in December 1982 and in some cases for the March 1983 sampling dates. In all cases, the abundances were statistically similar at all the other stations, except REFS, on these sampling dates. The species that exhibited these differences for the REFS station were *Mediomastus ambiseta*, *Mulinia lateralis*, [illegible], and the oligochaete species. [illegible] was consistently low for all the predisposal sampling dates. All other species investigated in detail did not exhibit any significant differences during the predisposal period.

77. Variances for the predisposal data were consistently higher within stations than between stations, suggesting that on a large scale (i.e., over the entire CLIS study area), the community was homogeneous. Conversely, on a

Table 5

Ranks of Community Dominants at the FVP Site During the Predisposal Period

Species*	May 82	Aug 82	Dec 82	Mar 83
Nucula annulata (B)	1	1	3	2
Mulinia lateralis (B)	2	5	2	3
Mediomastus ambiseta (P)	13	2	1	1
[illegible] (B)	6	8	4	4
[illegible] (P)	3	3	7	8
[illegible] sp. (O)	10	6	6	5
[illegible] (P)	5	4	13	10
[illegible] (R)	12	9	5	6
[illegible] (G)	9	19	8	9
[illegible] (B)	4	10	10	23
[illegible] (G)	7	7	17	18
[illegible] sp. (P)	21	16	9	7
[illegible] (A)	8	20	36	37

* A = anemone, B = bivalve, G = gastropod, O = oligochaete, P = polychaete, R = rhynchocoel.

small scale within a station, the community is heterogeneous (i.e., species abundances were patchily distributed).

58. The predisposal data were also used to determine the average percentage of change relative to the overall station mean for a given date. These data were necessary to detect differences between stations for the community variables as well as for some of the individual species abundances. Table [illegible] lists the range of percentage changes pooled for all predisposal dates. These percentages represent the magnitude of change necessary to detect statistically significant differences between two stations. When differences of these magnitudes were found between stations within a given date, the parameters for these stations were determined to be statistically different from one another.

Table 6

Detectable Differences for Selected Variables Based on Predisposal Data

Variable	Percentage of Change Between Stations/Time Considered Significant (Decrease - Increase)
Number of species per quadrat	20 - 32
Number of individuals per quadrat	41 - 118
[illegible]	69 - 110
[illegible]	59 - 62
[illegible]	49 - 80
[illegible]	30 - 48
[illegible]	63 - 103

REMOTS

79. BMD. The mixing-depth frequency distributions are shown in Figure [illegible] for the August 1982 and March 1983 predisposal surveys. The distributions are not significantly different at the $P = 0.05$ level (Student's t-test). The summer and winter apparent mixing depths, as manifested in the thickness of the high-reflectance surface sediment, are about 4 cm. In subsequent postdisposal REMOTS surveys, 4 cm has been found to be a typical mixing depth for the "equilibrium" infaunal community that lives within the silt-clay facies of the CLIS basin.

80. Infaunal successional stage. All 45 replicates of the 15 stations sampled in August 1982 showed the presence of head-down feeders (feeding pockets at depth). These station replicates were designated as being in a stage III sere. This does not mean that all of the head-down feeders belong to the same taxonomic group but, rather, this designation implies that the infauna within the surveyed area is uniform in a functional sense. The most common stage III taxon, bioturbating sediment to a depth of 4 cm in this part of the Sound, are members of the polychaete families Nephtidae and Maldanidae while protobranch bivalves bioturbate to 3-cm depths. In addition, all

station replicates showed the presence of small tubicolous polychaetes at or near the sediment surface. This near-surface assemblage was feeding on recently sedimented seston (a Stage I sere). Again, this does not imply that all of the Stage I taxa are the same. Several polychaete families were represented (e.g., Spionidae, Owenidae, Capitellidae). In summary, all of the surveyed stations had a Stage I-III successional status, suggesting that the trophic and functional diversity of the surveyed area was high and spatially homogeneous.

81. The March 1983 REMOTS survey again showed a dominance of Stage I-III seres. Just three replicates out of 45 showed only Stage I taxa present. The 12 replicates taken at the REFS station showed only one Stage I sere, with the other 11 in a Stage I-III condition.

82. OSI. The August 1982 and March 1983 predisposal OSIs are shown in Figure 8. Most values fell within the 10 and 11 classes. Other REMOTS surveys in CLIS have shown that OSI values of <6 indicate a recent disturbance or a stressed habitat. The predisposal values shown in Figure 8 suggest that the predisposal site was located in an area of the sound that was not disturbed or stressed in the recent past.

Summary: predisposal

83. The predisposal sampling indicated that the FVP site was characteristic of the silt-clay facies common to CLIS. Extensive surveys to examine the benthic infauna and organism-sediment properties indicated a very homogeneous environment. The patterns of species dominance and organism-sediment indices were also relatively consistent over time. The only differences noted between the disposal site and the REFS station were mean numbers of individuals per quadrat.

Postdisposal Characterization

Physical and chemical properties

84. As a result of the disposal operation, a dredged material mound of BRH sediments approximately 1.5 to 2.0 m deep was deposited at the CNTR station (Scott et al. 1985a). A REMOTS reconnaissance survey was conducted 3 weeks after the cessation of the disposal operations to map the dredged material thickness at the site. The zero isopleth of dredged material thickness in each compass direction was E, 400 m; N, 500 m; W, 500 to 100 m; and

S, 300 m (Figure 2). On the east transect where the benthic grab stations were located, thickness measurements were >10 cm at 150E, 4.8 cm at 250E and 3.4 cm at 300E. Of the area impacted by BRH sediments, over 90 percent was covered to a depth of ≤20 cm (Germano and Rhoads 1984).

85. Grain-size analysis. Following the disposal of BRH dredged material in early May 1983, stations located within 400 m of station CNTR showed the presence of a significant sand fraction, as determined both by sieve analysis (Figure 9) and REMOTS estimates of the major grain-size mode (Figure 10). The REMOTS data indicated that 58 percent of the station replicates had a major mode of very fine to fine sand. Most of these stations were located within 400 m of the CNTR station (Figure 11a, b, c, and d). Stations located beyond the 400-m perimeter, both on the thin dredged material apron and the ambient bottom, had a major grain-size mode in the silt-clay fraction comparable with the texture described for the predisposal bottom and REFS station.

86. REMOTS surveys indicated that this grain-size pattern persisted over the 2-year postdisposal period. Station CNTR showed evidence of surface scour for the first time in the January 1984 survey, where sand and shell fragments appeared to be concentrated within the upper 1 to 2 cm of the bottom sediment. This clean sand layer had been washed free of organics and fine particles, and it displayed high reflectance in profile images. This layer is interpreted as representing a surficial scour-lag deposit. All subsequent surveys have shown this scour surface to persist. In the posthurricane Gloria survey (23 October 1985), stations 150E and 100W also showed the development of an incipient sand- and shell-lag deposit. The timing of its appearance at these stations is attributed to increased scouring of the disposal mound by the hurricane storm surge.

87. The grain-size distribution of the REFS station has remained unchanged over the course of the postdisposal monitoring with the major mode being silt-clay and the sand component being less than 5 percent by weight (Figure 11e).

88. Boundary roughness. Analysis of the postdisposal small-scale boundary roughness data shows no apparent systematic temporal trends in modal roughness. All of the data are unimodal; that is, they have a central tendency and are right-skewed. Most values fell between the modal classes of 0.21 to 0.41 cm (class 2) and 0.63 to 0.84 cm (class 3) (Figure 12). Small-scale modal boundary roughness changes by a factor of 2 to 3 over the 3-year

period of monitoring. The only pattern to emerge from these data is a qualitative one. The origin of the small-scale boundary roughness in the summer and fall sampling periods is related to the presence of biogenic features, such as tube and fecal mound projections, burrow openings, and feeding depressions. The winter images showed that much of the roughness was related to erosion and redistribution of near-surface sediment.

89. No significant quantitative differences were detected in the modal small-scale bed roughness on the disposed BRH sediment of the FVP site and on that of the ambient bottom or REFS station.

90. Sediment chemistry. The distribution of dredged material was reflected in the concentrations of PAHs, PCBs, and copper in the surficial sediments at the FVP site (Table 7). A decreasing concentration gradient was exhibited by each chemical from CNTR to the 1000E station. Concentrations at 1000E were generally higher than those measured during the predisposal period (e.g., PAH sum = 5,300 μg/kg, PCBs = 71 μg/kg, Cu = 63 μg/kg) or at the reference station (e.g., PAH sum = 4,239 μg/kg, PCBs = 57 μg/kg, Cu = 63 μg/g). A temporal concentration gradient was also found, with the concentrations at CNTR exhibiting the most variability. Except for the CNTR and 200E stations, where dredged material thickness exceeded the core depth, the contamination levels were the highest in the sediment surface layer at 400E and 1000E.

91. The spatial and temporal changes in contaminant concentration are presented as percentages of BRH sediment in the 0- to 2-cm surface layer at CNTR, 200E, 400E, and 1000E from immediately after disposal June 1983 to October 1985 (Table 8). The sediment samples used for the percent calculations were not replicated, and, therefore, no variability estimates are available. However, certain trends in the data are evident. There was a gradient of BRH material that is a function of both distance from the center of the mound and time from disposal. BRH sediment concentrations were highest at CNTR and 200E immediately after disposal and decreased significantly through October 1984. Concentrations were elevated in December 1984 at CNTR and 200E and again in October 1985 at 200E. The BRH concentrations at 400E also decreased through time and, after March 1984, were only slightly higher than those at 1000E. These stations did not show the increased BRH concentration found at CNTR and 200E during the last two sampling dates. With the exception of the BRH concentration for December 1983, the concentrations at 1000E remained relatively similar throughout the study.

Table 7

Concentrations of PAH Sum, PCBs, and Copper from June 1983 to September 1984 in the Surficial Sediments at the FVP Site

Concentration	Station			
	CNTR	200E	400E	1000E
PAH Sum, μg/kg				
Jun 83	62,092	59,211	30,030	2,734
Jul 83	54,124	65,515	10,122	7,227
Sep 83	32,863	71,090	13,519	7,151
Mar 84	81,612	7,140	6,741	6,922
Sep 84	18,612	4,429	8,590	5,002
PCB 1254, μg/kg				
Jun 83	1,733	1,650	891	62
Jul 83	180	1,827	236	117
Sep 83	1,190	2,247	344	203
Mar 84	228	247	152	67
Sep 84	437	113	183	66
Copper, μg/g				
Jun 83	1,423	1,349	446	103
Jul 83	455	1,231	185	106
Sep 83	1,225	1,029	227	108
Mar 84	202	951	143	123
Sep 84	428	111	156	73

Table 8

Percent BRH Sediment in the Surficial Sediments at the FVP Site

Date	Station CNTR	200E	400E	1000E
Jun 83	44.5	41.1	12.5	1.8
Jul 83	15.0	37.4	3.3	1.6
Sep 83	32.0	36.7	4.9	2.0
Dec 83	32.8	36.1	9.5	4.4
Mar 84	4.4	2.2	1.9	1.8
Jun 84	9.5	15.6	0.5	0.7
Sep 84	10.0	0.8	3.5	0.5
Oct 84	2.6	--	0.2	1.6
Dec 84	35.1	11.3	0.0	1.0
Oct 85	0.2	21.0	0.0	0.0

92. The causes for the rapid decline of BRH sediments (as percent) in the surface layers after December 1983 are unknown. Storm-induced scour and resuspension could account for the concentration decreases at CNTR. The presence of scour surfaces in REMOTS images in January 1984 is indicative of these events, which would wash the highly contaminated fine sediments from the mound surface, leaving a sandier, less contaminated substrate at the surface of CNTR. The presence of 5 to 10 cm of dredged material at 200E is evidenced by the high percentage of BRH concentration through December 1983. The subsequent sharp concentration decrease may be related to scour and redistribution, but the bottom trawling activities reported near this station* could also account for the removal and redistribution of contaminated surface sediments.

93. The 1 to 2 percent of BRH sediment calculated for 1000E represents a quantitatively measured elevation above background and is supported by tissue residue data for the infaunal polychaete *N. incisa*. Additional documentation of contamination comes from examination of the PAH centroid

* Personal communication, October 1984, Frank Bohlen, University of Connecticut, Avery, Conn.

values, which indicate the presence of BRH sediment. REMOTS images from 1000E also showed a patchy distribution of black sediment at the surface. This contamination could have resulted from the initial disposal operation, the errant disposal of BRH material in the vicinity of 1000E, or the continuous transport of contaminated material from the disposal site.

Biological properties

94. Numbers of species. The immediate impact of the disposal of BRH dredged material at the FVP site was the burial of the benthic community within the 200-m contour. A statistically significant decrease in mean number of species per quadrat (Table 9) was found for the CNTR station immediately after the disposal operation, and these values remained low until the December sampling. The other three stations did not show any species decreases that could be attributed to the disposal operation. The number of species at the center station remained low through September 1983, after which the number of species recovering at that station rose sharply, as evidenced at the December 1983 sampling. Species densities measured in June, 1 year later, were still lower than those at the REFS station. However, by October 1985, CNTR consisted of significantly more species than did the REFS station (Table 9).

95. In addition to differences in species density at CNTR and REFS, the species composition between these stations was different. This is illustrated by comparing the numbers of species unique to the REFS and CNTR stations with the number common to both (Figure 13 and Appendix A). During December 1982 and March 1983 of the predisposal period, the numbers of species common to both stations were 30 and 40, or 67 and 77 percent of the total, respectively. Following disposal in June, July, and September, the common species dropped to 15, 16, and 19 species, respectively, or approximately one-third of the total. By December 1983, the common species outnumbered those unique to either station. This trend continued through June 1984, June 1985, and October 1985. Though the numbers of species unique to each station are still higher than the two predisposal dates, these data indicate that members of the ambient benthic community were colonizing the dredged material mound.

96. Numbers of individuals. The mean numbers of individuals at the REFS station, postdisposal, ranged from a low of 1,312/0.1 m^2 in September 1983 to a high of 3,228/0.1 m^2 in October 1985 (Table 10). Similarly, at 400E and 1000E, the lowest number of individuals per quadrat was also found in September 1983. At CNTR and 200E, the pattern of abundance was clearly

Table 9

Mean Number of Species per Quadrat (0.1 m^2) at the FVP Site During the Postdisposal Phase

Date	Station				
	CNTR	200E	400E	1000E	REFS
Mar 83*	33.2	34.0	33.0	32.4	29.0
Jun 83	7.2**	27.2	30.2	32.6	30.8
Jul 83	8.0**	30.0	34.6	32.6	32.5
Sep 83	11.4**	23.8	28.2	28.4	29.2
Dec 83	31.6**	37.4	40.8	43.8	37.4
Jun 84	29.7**	--	--	--	39.3
Jun 85	19.3**	--	--	--	29.7
Oct 85†	37.3**	--	--	--	31.0

* Predisposal.

** Significant differences in species density between CNTR and REFS stations ($P > 0.05$).

† Posthurricane.

affected by the disposal of BRH dredged material. The CNTR station had significantly lower densities than were found at 400E, 1000E, and REFS during June, July, and September. The density of individuals at 200E was similar to REFS during June but decreased significantly during July and September. Recolonization at the CNTR had occurred by December with abundances similar to those at 400E and 1000E, whereas abundances at 200E and REFS, although similar, were significantly lower ($P > 0.05$). Significant depressions in abundance recurred at CNTR during the following two summers, but by October 1985, the mound had recolonized to abundance levels equal to those at REFS. Much of this recolonization, as will be shown, was due to the heavy recruitment of only a few species.

97. Dominant species. The mean densities for the dominant species during the predisposal and postdisposal periods are shown in Appendix B. The dominant species during the predisposal period was the deposit-feeding bivalve *Nucula annulata*. Following disposal, a gradient of density decreased from the REFS and 1000E stations to CNTR (Figure 14a). By July, abundances at

Table 10

Mean Number of Individuals per Quadrat (0.1 m^2) at the FVP Site During the Postdisposal Phase

Date	Station				
	CTR	200E	400E	1000E	REFS
Mar 83**	5,438	6,502	6,915	7,525	5,035
Jun 83	52**	2,413	3,916	5,387	2,319
Jul 83	213**	929	3,372	3,749	2.206
Sep 83	218**	839	1,232	1,222	1,312
Dec 83	4,463**	2,193	4,489	4,830	2,244
Jun 84	710**				3,075
Jun 85	573**				2,068
Oct 85+	3,701**				3,228

* Predisposal.

** Numbers of individuals at CNTR and REFS were significantly different at P > 0.05.

+ Posthurricane.

200E were significantly lower than those at 400E, 1000E, and REFS. These differences at 200E persisted into September, with some recovery by December 1983. There was no recovery at the CNTR station during the subsequent 2.5 years (Figure 14b).

98. Relative abundances across all stations for the deposit-feeding polychaete *Mediomastus ambiseta* are illustrated in Figure 15a for each station and predisposal and postdisposal dates through December 1983. There were distinct seasonal abundance patterns for this polychaete, with maximum abundances in winter and early spring of 1982 and 1983 predisposal, and minimum densities in late summer and early fall. *Mediomastus* experienced statistically significant abundance decreases at CNTR and 200E in June and July 1983, as compared with 400E and 1000E (Figure 15a). Numbers at REFS and 200E were similar, however. Even though winter recruitment occurred across all stations in December 1983, the densities remained statistically lowest at CNTR, 200E, and REFS. Abundances were generally lower in June 1984 and 1985, and apparently normal recruitment occurred in October 1985 at both CNTR and REFS (Figure 15b).

99. The seasonal abundance patterns of the filter-feeding bivalve *Mulinia lateralis* were very similar to those of *Mediomastus*, in that the population reached its maximum density in the winter. The densities at CNTR and 200E were significantly lower than at the other stations through the summer of 1983, probably as a result of burial by the dredged material. Normal recruitment patterns were seen at all stations in December 1983, with the greatest abundances occurring at CNTR (Figure 16a and b). Summer abundances for this species were low in 1984 and 1985 with predisposal densities being reached in October 1985 (Figure 16b).

100. The deposit-feeding oligochaeta were a common community dominant throughout this study. They became most abundant from December 1982, predisposal, through the postdisposal period to October 1985 (Figure 17b). As this group of organisms is taxonomically complex and is probably represented by two or more species, no seasonal recruitment patterns were evident. The group was significantly affected by the disposal at the CNTR station, where their abundance remained significantly below REFS through October 1985 (Figure 17a and b).

101. The deposit-feeding polychaete *Nephtys incisa* (Sanders 1956) showed generally decreasing population abundances throughout the study (Figure 18a) with no clearly evident seasonal patterns. The CNTR station exhibited significantly lower abundances during the summer following dredged material disposal. In December 1983, densities across all stations were statistically similar. Densities were again significantly depressed in June 1984 at CNTR. They remained low, but they were the same at CNTR and REFS in the summer of the following year. In October 1985, there was a significant recruitment at both CNTR and REFS, where the recorded densities approached predisposal levels (Figure 18b).

102. The long-lived bivalve *Yoldia limatula* was most abundant from December 1982, predisposal, through July 1983, just after disposal. Densities of this deposit feeder gradually decreased over that period to very low levels in September 1983 (Figure 19a). There was no replacement of the buried population at CNTR, although there were low levels (10 to 20/0.1 m^2) of recruitment and adult survival through October 1985. As was seen for *Nephtys*, densities at the REFS station did not approach predisposal levels until the summer of 1985 (Figure 19b). It appears from these data that these two species have abundance cycles on the scale of 2 to 3 years.

103. Three species of spionid polychaetes, *Polydora ligni*, *P. quadrilobata* and *Streblospio benedicti* showed very distinct recruitment patterns, exhibiting a significant preference for the dredged material mound. *Polydora ligni* was rare or absent during the predisposal period, but was recorded at all stations in July 1983 (Figure 20a). Densities were high at CNTR in December 1983 and June 1984. They were absent at both CNTR and REFS in June 1985, but again experienced significant recruitment on the mound in October 1985 (Figure 20b). A congener, *P. quadrilobata*, was also very abundant in the December 1983 samples.

104. *Streblospio benedicti* exhibited a very similar pattern, except that it had low densities when *Polydora* was abundant in July 1983 and was more abundant when the *Polydora* population was low in the next sampling period (September 1983) (Figure 21a and b). Both species were significant colonizers in December 1983 and June 1984 but were absent in June 1985.

105. One species showed significant recruitment at the FVP site during the last year of the study. The surface deposit feeder *Tellina agilis* was moderately abundant across all stations in December 1983; however, the REFS station showed the significantly lower abundances. Large-scale recruitment of *Tellina* occurred in October 1985 (Figure 22a and b). Another surface deposit-feeding bivalve, *Macoma tenta*, showed a similar distribution, although it was more abundant in the summers of 1984 and 1985 and became very abundant in October 1985 (Appendix A, Table 1).

106. Cluster analysis of species abundances. A cluster analysis was conducted to synthesize the data previously presented on species abundances over space and time. The hierarchical cluster analysis, using euclidean distance as the measure of similarity, is shown in Figure 23 for the CNTR and REFS stations over all sampling dates.

107. This analysis breaks the 20 CNTR-REFS-date combinations into three distinct groupings, based on species composition and relative abundance. The largest group (I) contains all of the REFS samples, all of the predisposal CNTR samples, and one postdisposal CNTR sample. Within Group I, several station-date combinations are quite similar to each other. For example, CNTR and REF samples taken in May 1982 are very similar to each other and dissimilar to the rest of Group I. The December 1982 CNTR and March 1983 REFS (predisposal) samples are, likewise, similar to each other. The next subgroup contains four sample sets, those from the REFS station in December 1982, and

March, June, and July 1983. The REFS December 1983 and June 1984 samples cluster next, followed by September 1983 and then June 1985 and October 1985. The most dissimilar member of Group I is the October 1985 sample set from the CNTR station.

108. Group II contains the immediate postdisposal samples from CNTR in June, July, and September 1983, which cluster together with the June 1984 and June 1985 CNTR samples. Although these CNTR dates cluster together, the generally high centroid distance joining these clusters, which is inversely related to similarity, indicates the dynamic nature of the species abundance patterns. The third group consists of only one station/date, CNTR in December 1983. This sample set could be interpreted as representing a transitional community having characteristics quite different from the rest of the postdisposal samples from CNTR and any of the samples collected from REFS.

109. Summary: quantitative grab sampling. The numbers of species at the 200E station had returned to background levels by December 1983, whereas the recruitment at CNTR was lagging behind what was found at 400E, 1000E, and REFS. By mid-1984, species numbers were similar at CNTR and REFS, with a more diverse assemblage present on the mound.

110. In the samples that were analyzed, two periods of significant recruitment at CNTR were noted, December 1983 and October 1985. In December 1983, there was significant recruitment of *Mulinia*, *Polydora* (two species), and *Streblospio*, which were not similarly recruited to REFS. In October 1985, recruitment patterns at the two stations were more similar, except for higher abundances of *Mediomastus* and *Tellina* at CNTR and high densities of *Nucula* at REFS, with no significant *Nucula* recruitment to the CNTR.

111. BMD. REMOTS estimates of BMD are given in Figure 24 for stations CNTR and REFS over the study period. The predisposal data sets indicate that the mixing depths were relatively deep at both the CNTR and REFS stations (4 to 5 cm). These two sampling dates are significantly different from all other dates at the 0.05 level of significance (Duncan's Multiple Range Anova Test performed on rank-ordered data). Following disposal, the BMD was shallower at CNTR than at the REFS station for all dates with the exception of the post-hurricane survey in October 1985. This last survey showed considerable surface erosion and redistribution of sediment. The apparent loss of about 2 cm of mixed surface sediment at the REFS station, relative to the preceding June 1985 survey, may be related to storm erosion. If the 0.05 level of

significance is chosen to reject the null hypothesis, seven sampling periods show BMDs to be significantly shallower at CNTR than at the REFS station (Figure 24). Most of these sampling dates fall within the 1984 survey year.

112. BMD-frequency histograms for the entire FVP REMOTS data set are shown in Figure 25. The predisposal data were unimodally distributed with the major mixing depth modes falling within the 3.5- to 4.0-cm (August 1982) and 4.0- to 4.5-cm (March 1983) classes. Immediately following disposal, the BMD distributions were bimodal (June, July, and August 1983). This bimodality is explained by the location of stations on either BRH dredged material (low value model) versus those on the ambient seafloor near the FVP site or at REFS (high value mode). Those stations that lie within the BRH dredged material are CNTR, west to between stations 250W and 500W, east of CNTR to between 400E and 500E, north of CNTR to between 250N and 400N, and south of CNTR to between 200S and 300S. Stations 200N/300W, 200N/300E, and 200S/300W are also located within the apparent influence of BRH sediments.

113. Immediately following completion of the disposal operation, the BMD was zero. The shift in the major mode over the period June 1983 to January 1984 shows that this mixing depth went from an initial value of zero to 4 cm over a period of about 100 to 200 days. The uncertainty in the time is related to the sampling hiatus between August 1983 and January 1984. This yields a daily rate that ranges between 200 to 400 μm/days. This estimate gives the rate of depression of the biogenically mixed zone into the bottom by both fluid and particle bioturbation. The bimodality in mixing depths disappeared in the January 1984 survey when the BMD at the FVP site converged with values measured at the REFS station. The January 1984 date was the first time that a scoured sand and shell lag deposit was noted at CNTR. The BMD was significantly shallower at CNTR from this date onward, through all of the following 1984 sampling dates. This anomalously shallow mixing depth at CNTR is attributed to the associated physical disturbance, the effect of this disturbance on the colonization process, and infaunal mixing depths.

114. The REFS station BMD was significantly different from that measured at the FVP site at the $P > 0.5$ level on the June 1985 sampling date. On this same date, the mixing depth at CNTR and REFS was also statistically different ($P = 0.05$). The June survey revealed the reappearance of reduced black sediment at or near the sediment surface at the FVP site.

Eighty percent of the FVP images showed this phenomenon. None of the REFS replicates showed this feature. This black surficial sediment is assumed to be related to the exposure of reduced BRH dredged material at the sediment surface. The mechanism of exposure is not known (see Discussion in Part IV).

115. One of the effects of the passage of Hurricane Gloria over Long Island Sound on 27 September 1985 was the shift of the apparent BMD to very low values in the poststorm October 1985 survey. This shift was also apparent in data from the REFS station. The apparent shallowing of the mixing depths is attributed to the resuspension and redistribution of bottom sediments. This erosion event was manifested in REMOTS images as scour depressions and exposed and broken worm tubes. The presence of mud clasts at the sediment surface was observed at both the FVP site and REFS station.

116. Successional stages. The designation of the infaunal successional stage from REMOTS images is best done during warm-water months, when benthic populations are in a recruitment phase. Also, because the recognition of Stage III taxa from profile images depends on the presence of subsurface feeding voids, the higher water temperatures during summer are associated with high rates of bioturbation and well-developed feeding voids. For these reasons, the histograms of successional seres at CNTR and REFS stations are only for the warm-water months (Figure 26).

117. The predisposal August 1982 survey showed all of the stations to be in a Stage I-III condition. Immediately following disposal, Stage III taxa were eliminated from the CNTR station (Figure 26, arrow 1). This Stage I status continued to be maintained throughout the study period. The FVP site, as a whole, developed in a bimodal successional pattern immediately following disposal. All stations located on the BRH mound were populated by dense assemblages of opportunistic polychaetes identified as Stage I seres (Figure 26, arrow 2), whereas many stations located near the edge of the dredged material, or on the ambient seafloor, remained in a Stage I-III sere. Over the study period, recolonization has resulted in Stage III taxa reappearing on stations located near the edge or distal flanks of the mound. The REFS station successional status remained essentially unchanged through August 1983. In June 1984, a major shift at the REFS station to a dominance of Stage I seres (Figure 26, arrow 3) was detected. Although the cause for this retrograde shift is unknown, it may be related to the intensive disturbance of the REFS station by the FVP sampling program itself. A patchy distribution of

Stage I-III and Stage I seres has populated the REFS since the June 1984 survey, while the passage of Hurricane Gloria may have contributed to the dominance of Stage I seres at the REFS station in October 1985 (Figure 26, arrow 4). In the September 1984 survey, the appearance of patchy distributions of tubicolous polychaetes and amphipods was noted at some stations at the FVP site and at the REFS station. These are identified as Stage I-II seres (Figure 26, arrows 5 and 6).

118. <u>OSIs.</u> Figure 27 shows the OSI mean values for CNTR and REFS stations over the study period. The predisposal dates show that the indices were uniformly high (between 10 and 11) at both sites. The total possible range of this parameter is -10 (azoic, anoxic, and methanogenic sediment) to +11 (deep RMD populated by Stage III infauna). In previous REMOTS work at Long Island Sound disposal sites, OSI values <6 indicate recent disturbance.

119. Following disposal, OSI values at CNTR were lower (yet remained positive) than at the REFS. The OSI values at CNTR continued to be significantly lower than those at REFS throughout the remainder of the study period. The mean OSI dropped to a very low value at CNTR in October 1985. This was apparently related to the removal of surface sediment (and organisms) from two of the three station replicates by the hurricane storm surge.

120. The frequency distribution of OSI values for the REFS and CNTR stations and the FVP site overall are given in Figure 28. Again, the predisposal surveys show that most of OSI values fall within +10 to +11, indicating that the surveyed areas had a uniformly high (Stage I-III) habitat value. Following disposal, the OSI-frequency distributions became bimodal with most of the lower values (<6) being related to stations directly associated with BRH dredged material. The OSI values at the CNTR were significantly lower than those at the rest of the FVP station values in January, June, and December of 1984. This is attributed to the appearance of the sandy scour-lag surface that was documented from the January 1984 survey onward. Modal OSI values increased from June [illegible] (model OSI = 3) to July 1983 (modal OSI = 4), August [illegible] (modal OSI = 5), and January 1984 (modal OSI = 6) and maintained a value of OSI = [illegible] from June 1984 to March 1985. In June 1985, there was an apparent retrograde in the indices with many falling within the OSI classes [illegible]. This phenomenon is related to the appearance of reduced sediments at the sediment surface, resulting in lower OSI indices as the RMD values decreased.

121. The October 1985 survey showed a marked effect of Hurricane Gloria on the distribution of OSI values. This poststorm distribution is comparable with the first postdisposal survey conducted in June 1983, with many OSI values falling below 6 and some station replicates exhibiting negative OSI values. The REFS station values fall into a wide range of OSI classes (2 to 10), suggesting that the hurricane also affected the REFS site.

122. Cluster analysis--REMOTS. A hierarchical cluster analysis was conducted using REMOTS data and the results from quantitative grab samples to determine if there were any major station or date groupings. The data used for this analysis included the BMD, OSI, mean number of species per quadrat, and mean number of individuals per quadrat. There were eight sampling dates when grab sample and REMOTS surveys were considered to be compatible; these included one predisposal date, March 1983, and all of the grab sampling post-disposal dates (Figure 29).

123. Two distinct groupings emerged from this analysis; the predisposal samples at both CNTR and REFS stations combined with all REFS data (Group I), and all the postdisposal CNTR dates (Group II). In Group I, the predisposal CNTR survey was quite similar to the data collected in June 1985 and those throughout 1983. The REFS 1984 survey was the most dissimilar member of this group. This date exhibited the lowest mean OSI (Figure 27) of the group and, conversely, the highest number of species (Table 9) making it fairly unique. In addition, five of the six replicate images taken at REFS in June 1984 were classified as a Stage I assemblage (Figure 26) and had high densities of *Mediomastus* and oligochaetes, although the community was dominated by the bivalve *Nucula*.

124. Group II consisted of two subgroups. The surveys conducted at CNTR immediately after disposal in the summer of 1983 were very similar to each other, and they clustered closely with the CNTR data collected in June of 1984 and 1985. These dates were characterized by low OSIs (Figure 27), low BMDs (Figure 24), and low numbers of individuals (Table 20). The other sub-group contained CNTR and REFS in October 1985 and CNTR in December 1983. These station clusters had high numbers of species (Table 9) and individuals (Table 10) but low OSIs (Figure 27) and BMDS (Figure 24).

125. The uniqueness of these three samples, although not ordered exactly the same, was evident using a totally independent data set in the cluster analysis for relative species abundances (Figure 23). It appears that

the CNTR station in December 1983 was similar in some respects to REFS and CNTR stations in October 1985, following Hurricane Gloria. The analyses indicate that the posthurricane recolonization process occurring in October 1985 was not unlike the recolonization of the BRH dredged material 5 to 6 months following disposal.

126. Summary--REMOTS. REMOTS surveys indicated a significant change in the physical properties of the dredged material disposal mound as compared with the surrounding ambient stations and REFS. A sandy surface was found soon after disposal and continued throughout the survey period. The BMDs on the mound (CNTR and other mound stations) increased at a rate of 200 to 400 μm/day, returned to a unimodal condition, and appeared to converge with the BMD at REFS by January 1984. Following this date, however, physical scouring arrested the BMD at the CNTR to levels significantly shallower than those at the REFS station.

127. The OSI over all of the mound stations developed a bimodal frequency distribution that persisted throughout the study period. In addition, OSI values at the disposal site CNTR were consistently lower than at REFS. The FVP site as a whole showed a successional retrograde in June 1985, in conjunction with the appearance of black (anoxic) sediment at or near the surface in 80 percent of the stations surveyed. Following Hurricane Gloria in early October 1985, all stations sampled (including REFS) experienced a successional retrograde because of severe erosion and bottom resuspension. These erosional effects were comparable, in terms of REMOTS parameters, with those measured at the FVP site immediately following the disposal of BRH sediments.

PART IV: DISCUSSION

128. The objectives of this report are to describe the effects of the disposal of dredged BRH sediments on the ambient (predisposal) community and to describe the mode and pattern of recolonization of the FVP site. The recolonization process has been measured by documenting the rate of recolonization of the FVP site and comparing this with the ambient (control) community. The parameters used to describe recolonization and convergence with the ambient system are species numbers, abundances of numerically dominant species, degree of infaunalization (successional stage), and BMD of the bottom sediments (another measure of infaunalization).

The Ambient Community

129. Recovery of a disturbed habitat can be defined as a return to background or ambient conditions. These ambient conditions could be based on those present at a site prior to the disturbance or those relative to a reference site or some combination of both. The predisposal surveys at the FVP site were conducted to examine the spatial heterogeneity of the site and to assess ambient predisposal conditions relative to the reference site (REFS).

130. As noted previously, the predisposal benthic community at the FVP site was characteristic of the soft-bottom, nonperturbed system in Long Island Sound. This *Nephtys-Nucula* community (Sanders 1956) occurs where organic concentrations are between 1- and 10-mg carbon/gram of sediment with most of the grain sizes falling within the silt-clay range (≥ phi). Typically, on a small scale (within station), these species abundances are patchily distributed, displaying a mosaic species distribution. Replicate station grabs contained almost all the species but had different population abundances of individual taxa. On a larger scale (i.e., the entire disposal area), these population mosaics were consistent over the whole sampled site. This community structure and its component species appear to be well adapted to silty sediments and is characteristic of similar biofacies described for Long Island Sound (Sanders [illegible]), Narragansett Bay (Phelps 1958), and Buzzards Bay (Sanders [illegible]).

[illegible]. Few differences were detected between stations prior to the disposal operation, both for the quantitative grab samples and REMOTS parameters.

Where station to station differences were detected, they appeared to be local anomalies. No large-scale disturbance gradients were apparent in the baseline data. One exception to this general observation is that the REFS station exhibited a temporal pattern of significant differences in some species abundances prior to the disposal operation. The species composition, rank abundances, and REMOTS parameters showed the REFS station to be qualitatively very similar to the disposal site. Given that the trends in seasonal and yearly abundances were similar at both the FVP site and REFS station, the REFS site appeared to be appropriate for making comparisons with postdisposal changes measured at the FVP site.

132. The benthic community, sampled at the FVP site prior to disposal (baseline) and off the dredged materials following disposal (up to December 1983), was dominated by a subsurface infaunal deposit-feeding assemblage consisting of the protobranch bivalves *Nucula annulata* and *Yoldia limatula* and the polychaete worm *Nephtys incisa*. All three of these organisms are Stage III taxa (sensu Rhoads and Germano 1982) with mean life spans that greatly exceed 1 year, and reproduction may take place once or twice a year. They are important in bioturbating the sediment column, and this biogenic mixing controls both pore water and solid-phase chemistry. This subsurface deposit-feeding assemblage was vertically overlain by near-surface populations of the deposit-feeding polychaetes *Mediomastus ambiseta* and the suspension-feeding mactrid bivalve *Mulinia lateralis*. These latter two species are well-known members of Stage I seres representing opportunistic adaptive strategies. Mean life spans are less than 1 year, and reproduction of the population is several times per year. The sympatric association of opportunistic colonizers (Stage I taxa) with longer lived species (Stage III taxa) is common in estuaries and embayments. These early colonizers, however, can also be very abundant on disturbed bottoms. This assemblage type has been previously described for the CLIS silt-clay facies (Sanders 1956, Michael 1975) and for the silt-clay basinal facies of Buzzards Bay (Sanders 1956).

Recolonization Mechanisms

133. The recolonization of a dredged material disposal site can occur via three mechanisms: vertical migration of the buried assemblage through the dredged material from the underlying natural bottom, horizontal immigration of

adult organisms from the surrounding ambient bottom, and larval recruitment from the plankton (Maurer et al. 1981a). In a series of experiments to assess the ability of polychaetes, molluscs, and crustaceans to vertically migrate through an overburden of sediment, Maurer at al. (1981a, 1981b, 1982) found this mechanism to have more significance than previously thought (Diaz and Boesch 1977). *Nucula proxima* was able to escape from burial by 50 cm of fine-grained sediments, but 40 cm of fine sand was a lethal burial depth to *Nucula*; this protobranch could not migrate vertically through 1 m of dredged material (Maurer et al. 1981a, Krantz 1972). In other studies with bivalves also indigenous to CLIS, Krantz (1972) found that the critical escape depth for *Yoldia* was limited to ≤40 cm. Saila, Pratt, and Polgar (1972) found that *Mulinia* and *Nephtys* could burrow upward through 21 cm of dredged material in 24 hr.

134. The burial of these species at CNTR would appear to exceed their critical escape depths because of the 1- to 2-m depth of the dredged material at that station. At a burial depth of 10 to 20 cm, found at 200 E, *Nucula*, *Yoldia*, *Mulinia*, and *Nephtys* appear to have the ability to burrow upward through BRH sediments. This would account for the recorded abundances of these species at that station immediately postdisposal in June 1983. However, the density decreases of *Nucula* by December 1983, *Yoldia* by September 1983, and *Mulinia* in July 1983 suggest that these bivalve populations may have experienced subsequent mortalities. Laboratory studies, conducted as part of the FVP, found no significant lethal effects after 10-day exposures to BRH sediments for *Nucula*, *Mulinia*, *Yoldia*, or *Nephtys* (Rogerson, Schimmel, and Hoffman 1985). Small *Yoldia* avoided burrowing into BRH sediments, and *Nephtys* preferred to burrow into clean sediments when given a choice.

135. The recolonization of dredged material by both active and passive dispersion of adult organisms is another possible mode of recolonization (Santos and Simon 1980). Because of the limited mobility of bivalves, this mechanism is most applicable to polychaetes and crustaceans, which are known to be active members of the near-bottom plankton (Thomas and Jelly 1972; Dean [illegible]). At the FVP site, crustaceans were not found to be a dominant component of the ambient community, and therefore this class would not be expected to be important colonizers of the site as adults. Santos and Simon [illegible] found that errant polychaetes such as [illegible] (and for this study [illegible] were [illegible] colonizers of naturally defaunated sediments in Tampa Bay,

but, as noted above, this would appear to be ruled out for the FVP site, as *Nephtys* prefers sediments cleaner than those at the BRH disposal mound.

136. The significant role of larval recruitment in the recolonization of defaunated habitats, including dredged material, has been documented in several experimental and field studies conducted in Long Island Sound (Rhoads, Aller, and Goldhaber 1977; McCall 1977; Rhoads, McCall, and Yingst 1978; Zajac and Whitlatch 1982a and 1982b; Germano 1983). With few exceptions, the dominant early colonizers of defaunated plots of sediment were the same species as those found in this study: *Mediomastus*, *Mulinia*, *Streblospio*, and *Polydora*.

137. In McCall's experiments at two sites north of the CLIS (McCall 1977, 1978), the numbers of species colonizing experimental disturbance plots were similar to those on the adjacent ambient seafloor 3 months after the disturbance. However, the species composition was quite different. At the FVP site, similarity in species numbers among mound stations and the rest of the sampled sites was not achieved until 6 months later (December 1983), at which time a majority of the species found were common to both CNTR and REFS. In contrast to McCall's findings that these early colonizers died off during the winter, the early colonizers of the FVP site (*Polydora*, *Mediomastus*, *Streblospio*) maintained high abundances through December 1983.

138. McCall (1977, 1978) also found that the longer lived species *Nucula* and *Nephtys* tended to settle in lower densities 2 to 3 months following a disturbance and maintained generally lower population densities. This phenomenon appears to hold true for *Nephtys* and *Yoldia* in this study. These Stage III taxa did not recolonize the mound until December 1983 and were present in low densities comparable with their densities at the REFS station through the next 2 years.

139. The initial recolonization of another dredged material site in CLIS was followed by Rhoads, Aller, and Goldhaber (1977) from the termination of disposal in June 1974 through April 1975. The dredged material from New Haven Harbor was the first large disposal project in CLIS. Colonization was initially dominated by the polychaetes *Nephtys*, [illegible], and [illegible], followed temporally by the bivalves [illegible] and *Mulinia* in November 1974 and later. The early appearance of *Nephtys* on the New Haven mound was attributed to lateral adult migration. A similar pattern was found at the FVP site, with the recolonization sequence starting in June with *Mediomastus*, followed by [illegible], [illegible], and finally, [illegible] in December 1983.

Colonizing Sequence and Successional Development

140. The dominant species discussed previously can be categorized as to their successional role in the colonizing sequence described by Rhoads and Germano (1982 and in press), Rhoads and Boyer (1982). In this study, *Nephtys*, *Yoldia*, *Nucula*, and malanid polychaetes were considered to belong to the end-member Stage III sere because of their deep subsurface deposit feeding and because of significant bioturbation of Long Island Sound sediments. Early colonizers of near-surface sediments or Stage I taxa were here represented by *Mediomastus*, *Polydora*, *Streblospio*, and *Mulinia*. To examine the relative contributions of these two end-member stages to the community at CNTR and REFS, the mean abundances of the species in each group were summed and are presented in Figure 30a and b.

141. Prior to disposal, high densities of the Stage I polychaete *Mediomastus* were recorded in the winter and early spring at both stations; *Mediomastus* was still dominant at REFS during June and July 1983 following disposal. The Stage I taxa maintained relatively similar abundances at REFS until October 1985, with the exception of two dates, September 1983 and June 1985. At the CNTR station, Stage I abundances, representing recolonization of the dredged material, were generally low through the summer of 1983 and increased in December 1983 and October 1985. These two dates also witnessed significant colonization of CNTR by *Mulinia* and *Mediomastus*. This may have been caused by the physical washing of the mound apex by bottom currents.

142. The Stage III organisms *Nephtys*, *Nucula*, and *Yoldia* maintained stable abundances at the REFS station during the predisposal period but showed a gradual decline at CNTR through March 1983, which primarily reflects decreases in *Nucula* abundances. Following disposal, Stage III faunae were absent from CNTR through September 1983 and reappeared in December 1983. At the REFS station, Stage III taxa showed a twofold increase in July 1983 followed by gradual decline through June 1984. The increase in June 1985 was followed by a decrease to low levels in October 1985.

143. These data are supported with interpretations of REMOTS data. All of the predisposal REMOTS surveys at the CNTR and REFS stations detected a successional Stage I on III (I-III) that is, Stage I colonizers inhabiting the near-surface sediments with Stage III deeper burrowing deposit feeders at depth. The CNTR station was classified as Stage I in all replicate images

(except one in June 1985) throughout the study, indicating the general low abundance of organisms of this end-member sere. Grab sampling data showed them to be an order of magnitude less abundant than in the predisposal surveys. The REMOTS interpretation of the changing successional status at the REFS station is also supported by the declining abundances of Stage III members in June 1984 and October 1985. The lowest abundances of the three Stage III members were recorded in June 1984 ($116/0.1\ m^2$). Five of six REMOTS images were classified as Stage I at that time. In June 1985, Stage III taxa increased in abundance, and only 7 of 18 REMOTS images were classified as Stage I. Again, in October, when *Nephtys*, *Nucula*, and *Yoldia* total abundances dropped from $445/0.1\ m^2$ to $143/0.1\ m^2$, 14 of 20 REMOTS images were characterized as Stage I. The densities of Stage I and Stage III taxa cannot be quantitatively compared with REMOTS parameters because small numbers of some keystone species, such as maldanid polychaetes, can have a significant effect on sediment properties and REMOTS parameters. Nevertheless, these two independent data sets do provide qualitatively comparable results. For example, the first time that large maldanids (those retained on the 1-mm mesh sieve) appeared at the CNTR station was in June 1985, which was the only time a Stage I-III assemblage was noted on REMOTS images from this station.

Physical Properties: Recolonization Impacts

144. One of the dominant factors controlling the development and species composition of benthic infaunal communities is sediment grain size (Sanders 1958; McNulty, Work, and Moore 1962). Infaunae tend to be specialized for living in either sand or fine-grained silt-clay sediments. Feeding strategies may differ significantly, with fine-grained sediments being dominated by deposit feeders and with sandy bottoms dominated by surface deposit feeders or suspension feeders (Rhoads and Young 1970). In addition, to ensure larval settlement in substrates suitable for later development and growth, many planktonic larvae of benthic invertebrates respond to specific cues, correlated with grain size, before they will settle and metamorphose in a given substratum (Meadows and Campbell [illegible]).

145. The community structure of several dredged material disposal sites in CLIS has been described from benthic samples taken from [illegible] through [illegible] (Brooks 1983). These data were compiled with subsequent data from [illegible]

through 1983, including the predisposal FVP samples, and subjected to multivariate analysis by Scott et al. (1985b). The findings of these two studies indicate that the dredged material mounds existing in CLIS through early 1983 were populated by the well-known *Nephtys-Nucula-Yoldia* assemblage. Two other major species groupings were also delineated. One group consisted of early colonizers of relatively recent disposed materials and included those early colonizers reported for the FVP site. The second group was an assemblage unique to the Stamford, New Haven, north mound, which has a sand cap (Brooks 1983). Species associated with this latter group were the polychaetes *Nephtys picta*, *Ampharete arctica*, and *Spiophanes bombyx* and the suspension-feeding bivalve *Ensis directus*. *Nephtys incisa* and *Nucula annulata* were notably absent from this assemblage.

146. The REMOTS images in January 1984 indicated for the first time the development of a scour surface at CNTR station and an increase in the sand-size fractions at the CNTR station. Because of the topographic relief of the mound (1.8 m) and its original sand-mud composition, the mound apex experienced a washing of the low-density organic fines from the sediment. A storm of 30 knots with a west-to-east wind direction could exert significant shear stresses of 0.5 to 1 dynes/cm^2 and entrain fine-grained natural sediments at the 15- to 20-m depths (Rhoads, Aller, and Goldhaber 1977; McCall 1978). The sandy nature of the CNTR station is reflected in the unique appearance of *Ensis* by December 1983 and of the polychaetes *Spiophanes bombyx* and *Nephtys picta*.

147. Of the species that colonized the CNTR and were unique to that station (Appendix A), only *Ensis* is adapted for a shifting sand habitat (Pratt 1973). The species making up a distinct sand fauna in eastern Long Island Sound, e.g., heavy-shelled bivalves and free-burrowing amphipods and polychaetes (Franz 1976; Pratt 1977; Reid, Frame, and Draxler 1979), were not present at the FVP site. The remaining CNTR colonizers, not present on the surrounding ambient bottom, are associated with stable sand, muddy sand, and mixed bottom types. The polychaete *Sabellaria vulgaris* builds a tube attached to shells, pebbles, or other tubes. The amphipod *Parametopella cypris* clings to sessile colonial animals (Bousfield 1973). *Nephtys picta* is found on muddy sand with shells or seaweed (Pettibone 1963). The other unique species require a stable substrate for movement ([illegible], [illegible]), for burrows ([illegible], [illegible], [illegible]), or as a basis for tubes ([illegible],

Clymenella). Several of these species are community dominants on muddy sand on the mid-Atlantic continental shelf (Pearce et al. 1981).

148. The data on species occurrences and relative abundances indicate that recolonization of the mound proper was progressing as expected through December 1983. However, the increasingly sandy nature of CNTR would be expected to foster the development of a different community. Although species numbers remained relatively high during the following two summers, the total number of individuals was drastically lower at CNTR than at REFS. The relatively low densities of *Nucula* and *Mediomastus* are the primary reason for this difference in density, which would be expected since these species prefer fine-grained sediments.

149. A study of the population dynamics of *Nephtys* at the FVP site has provided data on *Nucula* abundances at 200E and 1000E in March and September 1984 (Zajac and Whitlatch 1986; Pratt, personal communication*). In March 1984, densities at 200E and 1000E were 169 and 238 individuals/0.1 m^2, respectively. In September, the number of individuals was 135 and 297/0.1 m^2, respectively. These data are within the range of values recorded for these two stations through December 1983 (Figure 14a). These values indicate that *Nucula* was recolonizing the 200E station, where exposure to the more toxic, silty, BRH sediments would be greater than at the CNTR station.

Recolonization at the FVP, MQR, and Cap Sites

150. In addition to the FVP site, BRH dredged material was deposited at three other locations in CLIS. Two mounds of BRH sediment were deposited in close proximity to one another near the western border of the CLIS disposal area. These are called the Cap Sites, as they were used to assess the feasibility of physically capping the soft BRH sediment. The balance of the BRH sediment was deposited at a preexisting disposal mound called the Mill-Quinnipiac River (MQR) site, which is located in the SW quadrant of the CLIS disposal area. The disposal of BRH sediment took place at all of these sites within the period May through June 1983. These three BRH deposits provide an

---

* Personal Communication, June 1986, Sheldon Pratt, Research Associate, University of Rhode Island, Kingston, R. I.

opportunity to compare the mode and rate of colonization observed by REMOTS at the FVP site (an uncapped deposit) with capped BRH sediments.

151. BRH sediments at Cap Site 1 were capped with clean mud, and Cap Site 2 was capped with a layer of clean sand. Both the sand and mud capping materials were obtained from the relatively clean outer region of New Haven Harbor. The MQR site was also capped with New Haven Harbor mud following disposal of BRH materials.

152. The rate of recovery of the Cap, MQR, FVP, and REFS sites can be compared using the REMOTS OSI (Table 11). No faunal data from grab samples are available for further comparison of the Cap or MQR sites. Prior to disposal, all of the mean OSI values were high (>8.40), reflecting generally deep BMDs associated with Stage III seres. Following disposal of the BRH sediment and capping materials in June 1983, all of the disposal sites had mean OSI values of less than 6. By August 1983, the sand cap at Cap Site 2 had already become admixed with silt-clay. Fines were being deposited on the mound from the ambient suspended particle field. This deposition was particularly apparent on the western side of the mound, where 1 to 2 cm of silt and clay had accumulated over the sand cap (approximately 0.5 to 1.0 cm/month). This mud was subsequently mixed into the sand cap over the course of the monitoring period. As at the FVP site, the disposal operations at these sites were initially associated with the local extinction of Stage III seres, and the mode of colonization was the same as that described for the FVP site. Stage I polychaetes pioneered the colonization and initiated the shallow biogenic mixing that is characteristic of this sere. By September 1984, both capping sites had experienced significant increases in OSI indices. Cap Site 1 (mud capping mud) had 37 percent of its stations in a Stage III sere, whereas Cap Site 3 (sand) had only 6 percent in a Stage III sere. This difference probably reflects the difference in grain-size and surface-sediment organic content between the two capping sites. Subsurface deposit feeders are more likely to move into a muddy sediment than into a clean sand. A similar phenomenon may have been operating at the FVP CNTR station, which had a lower OSI than all mound stations combined. The sand cap site was populated by sparse populations of the tubicolous amphipod [illegible], a Stage II taxon known to prefer sandy substrata. REMOTS images also showed the presence of surface grazing caridean shrimp at several stations at Cap Site 2.

Table 11

Comparison of OSIs at the Cap, MQR, FVP, and REFS South Sites, 1983-1985

Site	Baseline*	Aug 83	Sept 84	Aug 85	Oct 85
Cap 1 (Mud)	8.84	5.86	7.77**	7.80	6.45
Cap 2 (Sand)	8.53	5.84	6.60**	8.35	8.00
MQR	8.43	5.63	5.90	7.00	5.10**
FVP	9.92 10.67†	5.82 5.00†	6.95** 4.00†	no data 6.00**††	4.47** 1.33**†
REFS	10.20	10.33	8.38	7.30	5.45**

* Baseline data were collected from the Cap Sites in April 1983, at MQR and REFS in January 1983, and at FVP in March 1983.

** Significantly different (P = 0.05) values from prior sampling date, Mann-Whitney U-test.

† CNTR station replicates only.

†† Data from June 1985.

153. The MQR site did not experience a significant increase in OSI values by September 1984. The mean MQR site value of 4.90 was the lowest recorded for any of the CLIS disposal sites at that time. One year later, Cap Site 2 (sand) had the highest OSI, and it has remained high even after Hurricane Gloria. The subsequent appearance of Stage III taxa at Cap Site 2 may have been associated with the increased concentration of silt-clay and organic matter in the sand cap over time.

154. Following the hurricane, all of the disposal sites experienced decreases in mean OSI values. These decreases were significant at the 0.05 level at the MQR, FVP, and the REFS sites. The sand cap apparently prevented the storm surge from eroding the surface of Cap Site 2, contributing to the higher poststorm OSI values at Cap Site 2 as compared with Cap Site 1. In contrast to the stable cap at Cap Site 2, the developing sand layer at the FVP CNTR station could not resist surface erosion, as evidenced by the very low OSI values following the hurricane. Little evidence exists in the REMOTS images for physical storm reworking of the MQR site. The decrease in the OSI at the MQR site is attributed to a rebound in the BMD. This can be caused by

an increase in sediment BOD and COD and/or a decrease in the BMD and mixing rate of the sediment. The slow rate of recovery of the MQR site relative to the other BRH sites, especially from August 1983 to August 1985, is unknown. The REMOTS data suggest that it is a failure of the Stage III taxa to successfully invade this sediment and that the chemistry of the deposit may be responsible for the anomalously slow recovery. In 1985, only two stations showed the presence of head-down feeders at the MQR site.

PART V: SUMMARY

155. The temporal pattern of recolonization of the FVP site consisted of two separate processes operating at different time scales. The first process was the immediate recolonization of the dredged material mound, which occurred during the first 6 months following disposal. Short-lived, early colonizing species populated the mound in significant densities and in some cases were most abundant at the CNTR station (*Mulinia* and *Polydora*). This phase of the recolonization of the FVP site was not unlike that seen for other disturbed sites within Long Island Sound and elsewhere. The greater abundances at the CNTR station are not surprising since many early colonizers thrive in disturbed or defaunated habitats (McCall 1977) where competition for space or the biologically mediated geochemical conditions of the sediment do not pose problems for recruitment.

156. The second component of the recovery process, which may begin concurrently with the initial colonization, is the progressive development of subsurface-bioturbation associated with the reestablishment of the long-lived species. The time scale of this process may be on the order of 1 to 2 years or more. It was not until 19 months after disposal that head-down feeding voids were observed on REMOTS images at the FVP site mound stations, even though the major frequency mode of the BMD at those stations had converged with that of REFS within 1 year. The CNTR station continued to have a significantly lower BMD, even though head-down deposit feeders from the ambient community were among the recolonizers. [illegible] abundances gradually declined from May 1982 through December 1983 at all stations. There was some recruitment at CNTR in December 1983. [illegible] densities remained low at both REFS and CNTR stations in June of 1984 and 1985, with significant recruitment occurring between June 1985 and October 1985 following Hurricane Gloria. [illegible] was recruited in equal densities at both REFS and CNTR sites between September and December 1983, and both stations showed similar population patterns throughout the study, except that [illegible] recruitment and subsequent density increases following Hurricane Gloria were greater at the REFS station. The recolonization pattern for [illegible] and [illegible] showed that the CNTR was recovering and converging with the REFS station. The protobranch [illegible], however, did not recolonize the mound in significant numbers, which is likely to

be related to the significant sand fraction at CNTR. *Nucula* is absent from other sand-covered disposal mounds in CLIS, as well.

157. The failure of the ambient Stage III assemblage (*Nephtys*, *Nucula*, and *Yoldia*) to become established at the CNTR station by June 1985 may have been due to grain-size effects, since other deep bioturbating organisms were present, although in low numbers. It may be that the sand lens on the surface of the mound was effectively capping the subsurface contaminated BRH sediments. As a result, when the head-down feeders grew to a size where feeding depths penetrated the subsurface contaminated silts, feeding activities and survival may have been impaired.

158. Hurricane Gloria had a major impact on the recovery process at the FVP site. Cluster analyses using dominant species abundances and REMOTS parameters, together with numbers of species and individuals, showed that the CNTR and REFS stations were virtually indistinguishable after Hurricane Gloria in October 1985. The mean number of species per quadrat was similar at these two stations, although the high numbers of individuals indicated that the mound was undergoing another colonization phase similar to that documented in December 1983. The retrograde conditions in BMD and OSI at the REFS station also indicated a disturbed bottom. This resulted from the storm-induced sediment entrainment that removed 2 to 4 cm of surface sediment in this part of Long Island Sound. In addition, the commonness of species composition in October indicated that extensive recolonization was occurring. Passive dispersal of adult organisms from the ambient seafloor bottoms to the mound may have also been involved in this process.

REFERENCES

Abbott, R. T. 1974. American Seashells, Van Nostrand, New York.

Bass, L. J. 1980. "DATMAN - A Scientific Data Management System," Technical Report 80-147, Computer Science Department, University of Rhode Island, Kingston, R. I.

Blake, J. A. 1971. "Revisions of the Genus *Polydora* from the East Coast of North America (*Polydora*:Spionidae)," Smithsonian Contributions to Zoology, Vol 75, pp 1-32.

Bousfield, E. L. 1973. Shallow Water Gammaridean Amphipoda of New England, Cornell University Press, Ithaca, N. Y.

Brooks, A. L. 1983. "A Study of the Benthic Macrofauna at the Central Long Island Sound Disposal Site, DAMOS," Contribution No. 24, US Army Corps of Engineers (NED), New England Division, Waltham, Mass.

Conover, W. J., and Inman R. L. 1981. "Rank Transformations as a Bridge Between Parametric and Nonparametric Statistics," American Statistician, Vol 35, pp 124-129.

Dean, D. 1978a. "Migration of the Sandworm *Nereis virens* During Winter Nights," Marine Biology, Vol 48, pp 99-104.

__________. 1978b. "The Swimming of Bloodworms (*Glycera* spp.) at Night with Comments on Other Species," Marine Biology, Vol 48, pp 99-104.

Diaz, R. J., and Boesch, D. F. 1977. "Impact of Fluid Mud Dredged Material on Benthic Communities of the Tidal James River, Virginia," Technical Report D-77-45, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Fauvel, P. 1927. "Polychaetes Sedentaires," Faune de France, Vol 16, pp 1-494.

Folk, R. L. 1980. Petrology of Sedimentary Rocks, Hemphill Publishing Co., Austin, Texas.

Franz, D. 1976. "Benthic Molluscon Assemblages in Relation to Sediment Gradients in Northeastern Long Island Sound, Conn.," Malacologia, Vol 15, pp 377-399.

Gentile, J. H., and Scott, K. J. 1986. "The Application of a Hazard Assessment Strategy to Sediment Testing: Issues and Case Study," Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems, K. L. Dickson, A. W. Maki, and W. Brungs, eds., SETAC Special Publication, Pergamon Press, New York, pp 1-17.

Germano, J. D. 1983. "Infaunal Succession in Long Island Sound: Animal-Sediment Interactions and the Effects of Predation," Ph.D. Dissertation, Yale University, New Haven, Conn.

Germano, J. D., and Rhoads, D. C. 1984. "REMOTS Sediment Profiling at the Field Verification Program (FVP) Disposal Site," R. L. Montgomery and J. W. Leach, eds., Dredging and Dredged Material Disposal, pp 536-544, American Society of Civil Engineers, New York.

Gossner, K. L. 1971. Guide to the Identification of Marine and Estuarine Invertebrates, John Wiley and Sons, Inc., New York.

Johnson, R. G. 1972. "Conceptual Models of Benthic Communities," J. M. Schopf, ed., Models in Paleobiology, Freeman Cooper Co., San Francisco, Calif., pp 148-159.

Kranz, P. M. 1972. "The Anastrophic Burial of Bivalves and Its Paleoecological Significance," Ph. D. Thesis, University of Chicago, Chicago.

Lake, J., Hoffman, G., and Schimmel, S. C. 1985. "The Bioaccumulation of Contaminants from Black Rock Harbor Dredged Material by Mussels and Polychaetes," Technical Report D-85-2, prepared by the US Environmental Protection Agency, Narragansett, R. I., for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Maurer, D., et al. 1981a. "Vertical Migration and Mortality of Benthos in Dredged Material--Part I: Mollusca," Marine Environmental Research, Vol 4, pp 299-319.

__________. 1981b. "Vertical Migration and Mortality of Benthos in Dredged Material--Part II: Crustacea," Marine Environmental Research, Vol 5, pp 301-317.

__________. 1982. "Vertical Migration and Mortality of Benthos in Dredged Material--Part III: Polychaete," Marine Environmental Research, Vol 6, pp 49-68.

McCall, P. L. 1977. "Community Patterns and Adaptive Strategies of the Infaunal Benthos of Long Island Sound," Journal of Marine Research, Vol 35, pp 221-266.

McCall, P. L. 1978. "Spatial-Temporal Distributions of Long Island Sound Infauna: the Role of Bottom Disturbance in a Nearshore Marine Habitat," M. L. Wiley, ed., Estuarine Interactions, Academic Press, New York.

McNulty, J. K., Work, R. C., and Moore, H. B. 1962. "Some Relationships Between the Infauna of the Level Bottom and the Sediment in South Florida," Bulletin of Marine Science, Vol 12, pp 322-332.

Meadows, P., and Campbell, J. 1972. "Habitat Selection by Aquatic Invertebrates," Advances in Marine Biology, Vol 10, pp 271-282.

Michael, A. D. 1975. "Structure and Stability in Three Marine Benthic Communities in Southern New England," Brookhaven Symposium on the Effects of Energy Related Activities on the Outer Continental Shelf, E. Monowitz, ed., pp [illegible].

Morton, R. W. 1982. "Status Report on Disposal Operations Central Long Island Sound Disposal Site," Contribution No. 25, Science Applications, Inc., to New England Division, US Army Corps of Engineers, Waltham, Mass.

Pearce, J. B., et al. 1981. "Benthic Fauna," MESA New York Bight Atlas 14, New York Sea Grant Institute, Albany, N. Y.

Pearson, T., and Rosenberg, R. 1978. "Macrobenthic Succession in Relation to Organic Enrichment and Pollution in the Marine Environment," Oceanography and Marine Biology Annual Review, Vol 16, pp [illegible].

Pettibone, M. H. [illegible]. "Marine Polychaete Worms of the New England Region," Bulletin of the US National Museum, Vol [illegible], pp [illegible].

Phelps, D. K. 1958. "A Quantitative Study of the Infauna of Narragansett Bay in Relation to Certain Physical and Chemical Aspects of Their Environment," M. S. Thesis, University of Rhode Island, Kingston, R. I.

Pratt, S. D. 1973. "Benthic Fauna," Coastal and Offshore Environmental Inventory, Cape Hatteras to Nantucket Shoals, Marine Publication, Series 3, University of Rhode Island, Kingston, R. I.

__________. 1977. "Predisposal Benthos Survey--Cornfield Point Spoil Disposal Area, Long Island Sound," Report to New England Division, US Army Corps of Engineers, Waltham, Mass.

Reid, R., Frame, A., and Draxler, A. 1979. "Environmental Baselines in Long Island Sound, 1972-1975," NOAA Technical Report, National Marine Fisheries Service, SSRF-738.

Rhoads, D. C. 1973. "A Report to the US Army Corps of Engineers on The Environmental Consequences of Dredge-Spoil Disposal in Central Long Island Sound," Report SR-15, New England Division, Waltham, Mass.

__________. 1974. "A Report to the US Army Corps of Engineers on The Environmental Consequences of Dredge-Spoil Disposal in Central Long Island Sound," Report SR-17, New England Division, Waltham, Mass.

Rhoads, D. C., Aller, R. C., and Goldhaber, M. B. 1977. "The Influence of Colonizing Benthos on Physical Properties and Chemical Diagenesis of the Estuarine Sea Floor," B. C. Coull, ed., Ecology of Marine Benthos, University of South Carolina Press, Columbia, S. C., pp 113-138

Rhoads, D. C., and Boyer, L. F. 1982. "The Effects of Marine Benthos on Physical Properties of Sediments: A Successional Perspective," P. L. McCall and M. J. S. Tevesz, eds., Animal-Sediment Relations, Plenum Publishing, New York, pp 3-52.

Rhoads, D. C., and Germano, J. D. 1982. "Characterization of Organism-Sediment Relations Using Sediment Profile Imaging: An Efficient Method of Remote Ecological Monitoring of the Sea Floor (REMOTS System)," Marine Ecology Progress Series, Vol 8, pp 115-128.

__________. In press. "Interpreting the Significance of Long-Term Changes in Benthic Community Structure: A New Protocol," Hydrobiologia.

Rhoads, D. C., McCall, P. L., and Yingst, J. Y. 1978. "Disturbance and Production of the Estuarine Sea Floor," American Scientist, Vol 66, pp 577-586.

Rhoads, D. C., and Young, D. K. 1970. "The Influence of Deposit-Feeding Organisms on Sediment Stability and Community Trophic Structure," Journal of Marine Research, Vol 28, pp 150-178.

Rogerson, P., Schimmel, S., and Hoffman, G. 1985. "Chemical and Biological Characterization of Black Rock Harbor Dredged Material," Technical Report D-85-9, prepared by the US Environmental Protection Agency, Environmental Research Laboratory, Narragansett, R. I., for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Saila, S. B., Pratt, S. D., and Polgar, T. T. 1972. "Dredge Spoil Disposal in Rhode Island Sound," Marine Technical Report No. 2, University of Rhode Island, Kingston, R. I., pp 1-48.

Sanders, H. L. 1956. "Oceanography of Long Island Sound 1952-1954, X, Biology of Marine Bottom Communities," Bulletin Bingham Oceanographic Collection, Vol 15, pp 345-414.

_________. 1958. "Benthic Studies in Buzzards Bay, I, Animal-Sediment Relationships," Limnology and Oceanography, Vol 38, pp 265-380.

Santos, S. L., and Simon, J. L. 1980. "Marine Soft-Bottom Community Establishment Following Annual Defaunation: Larval or Adult Recruitment?" Marine Ecology Progress Series, Vol 2, pp 241-253.

SAS. 1985. SAS User's Guide, Statistics, Version 5 Edition, SAS Institute, Cary, N. C.

Scott, K. J., et al. 1985a. "Field Verification Program (FVP)," R. W. Morton, J. H. Parker, and W. B. Richmond, eds., Disposal Area Monitoring System (DAMOS) Summary of Program Results, 1981-1984, DAMOS Contribution No. 46, Vol II, Part C-III, US Army Corps of Engineers, New England Division, Waltham, Mass.

_________. 1985b. "An Assessment of Long-Term Trends of the CLIS Infaunal Community," R. W. Morton, J. H. Parker, and W. B. Richmond, eds., Disposal Area Monitoring System (DAMOS) Summary of Program Results, 1981-1984, DAMOS Contribution No. 46; Vol IV, Part A-I, US Army Corps of Engineers, New England Division, Waltham, Mass.

Snedecor, G. W., and Cochran, W. G. 1980. Statistical Methods, 7th ed., Iowa State University Press, Ames, Iowa.

Thomas, M. L. H., and Jelly, E. 1972. "Benthos Trapped Leaving the Bottom in [illegible] River, Prince Edward Island," Journal of the Fisheries Research Board of Canada, Vol 29, pp 1234-1237.

US Environmental Protection Agency-(USEPA). 1979. "Methods for the Chemical Analysis of Water and Wastes," EPA-600/4-79-020, US Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio.

US Environmental Protection Agency/US Army Corps of Engineers (USEPA/CE). [illegible]. "The Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters; Implementation Manual for Section 103 of PL 92-532," Environmental Effects Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Zajac, R. N., and Whitlatch, R. B. 1982a. "Responses of Estuarine Infauna to Disturbance, I, Spatial and Temporal Variation of Recolonization," Marine Ecology Progress Series, Vol 10, pp 1-14.

_________. [illegible]. "Responses of Estuarine Infauna to Disturbance, II, Spatial and Temporal Variation of Succession," Marine Ecology Progress Series, [illegible], pp [illegible].

_________. [illegible]. "Population Dynamics of [illegible]: Model Development and Its Application to the Field Verification Program," Quarterly Report to the US Environmental Protection Agency, University of Connecticut, Storrs, [illegible].

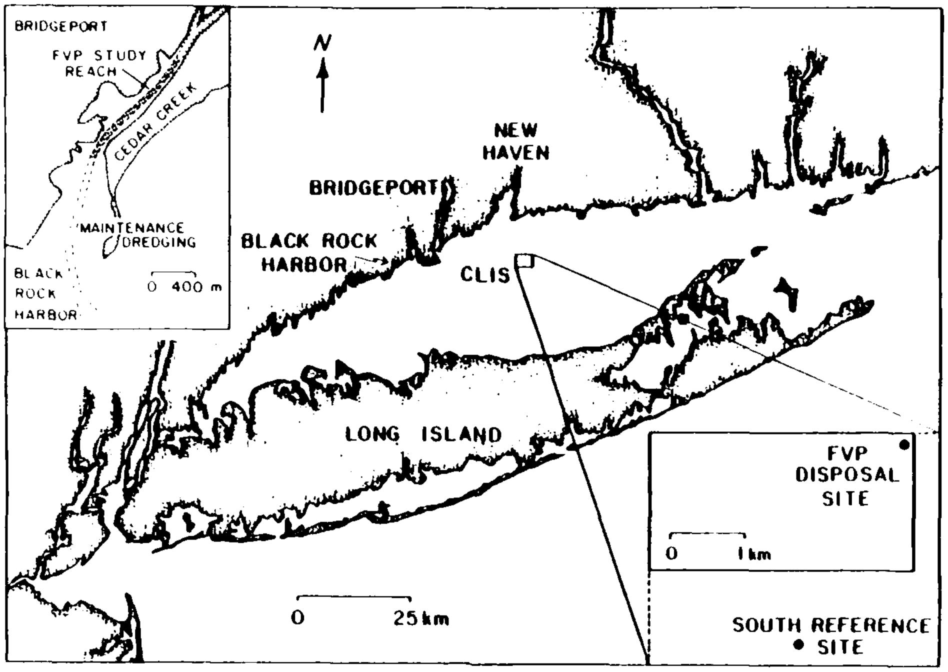


Figure 1. Central Long Island Sound (CLIS) disposal site and Black Rock Harbor (BRH) dredge site

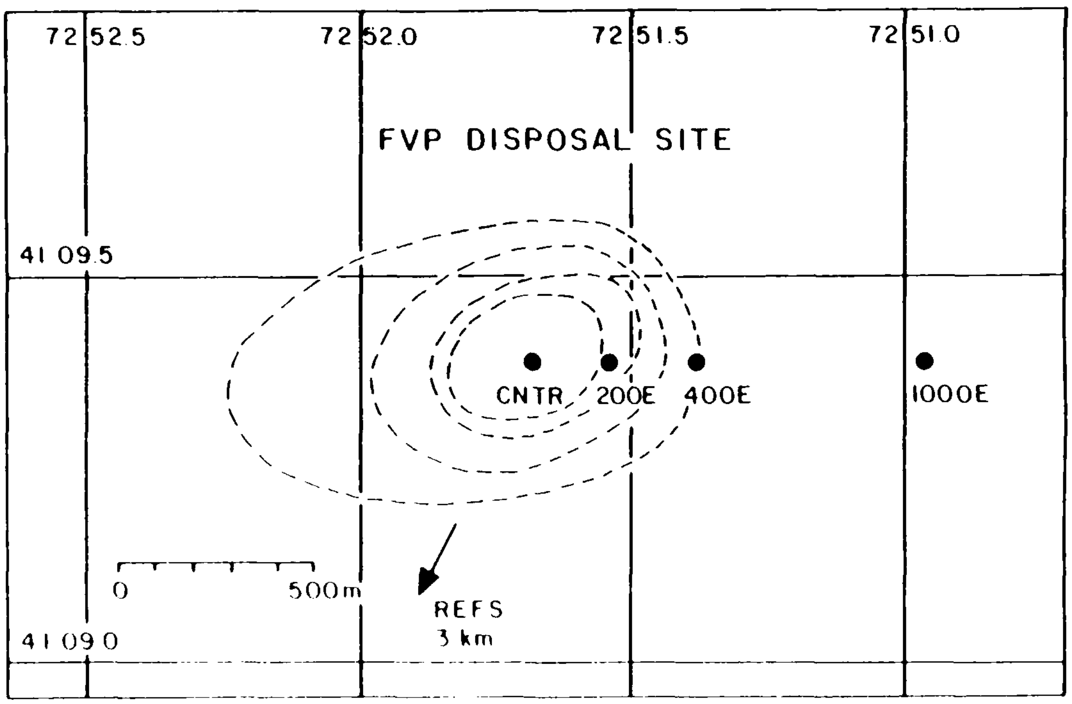


Figure 2. FVP sampling stations

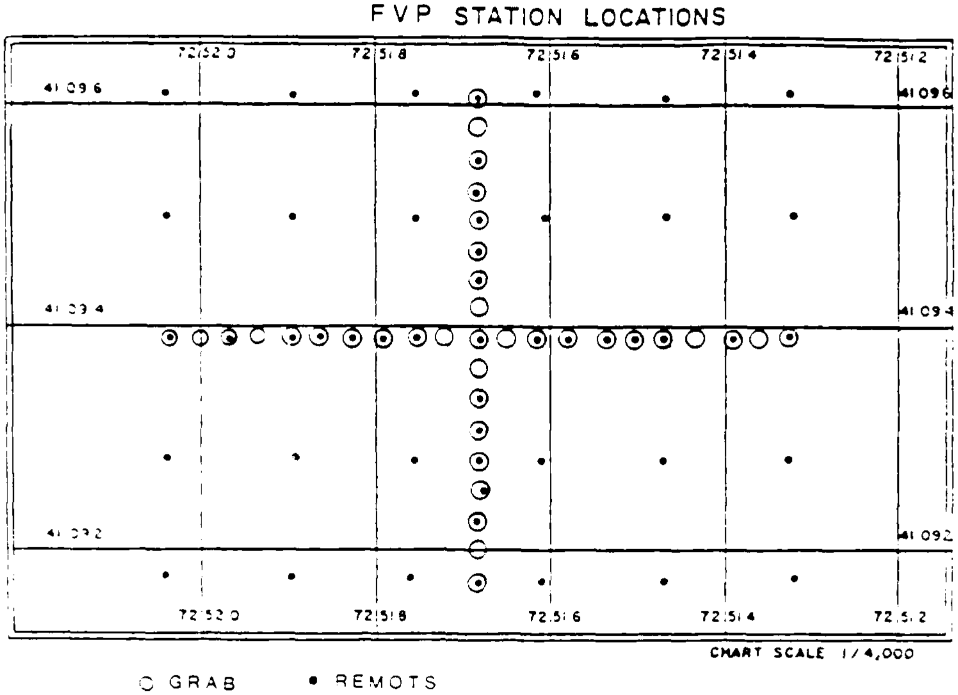


Figure 3. Sampling locations for REMOTS and quantitative grab samples May and August 1982

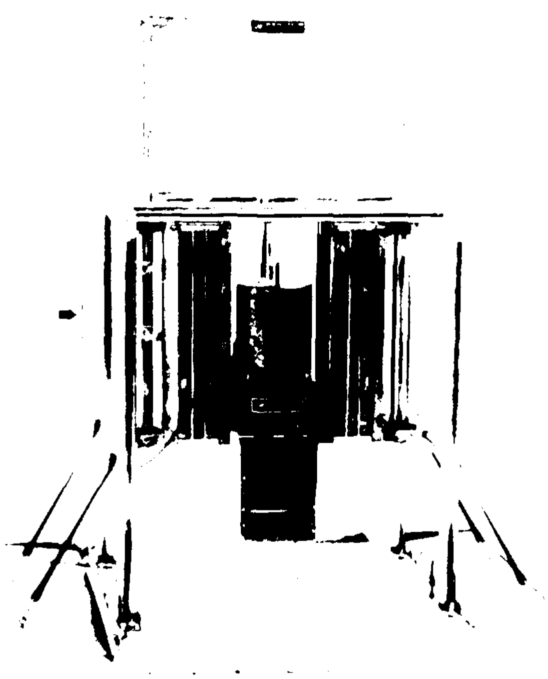


Figure 4. REMOTS interface camera

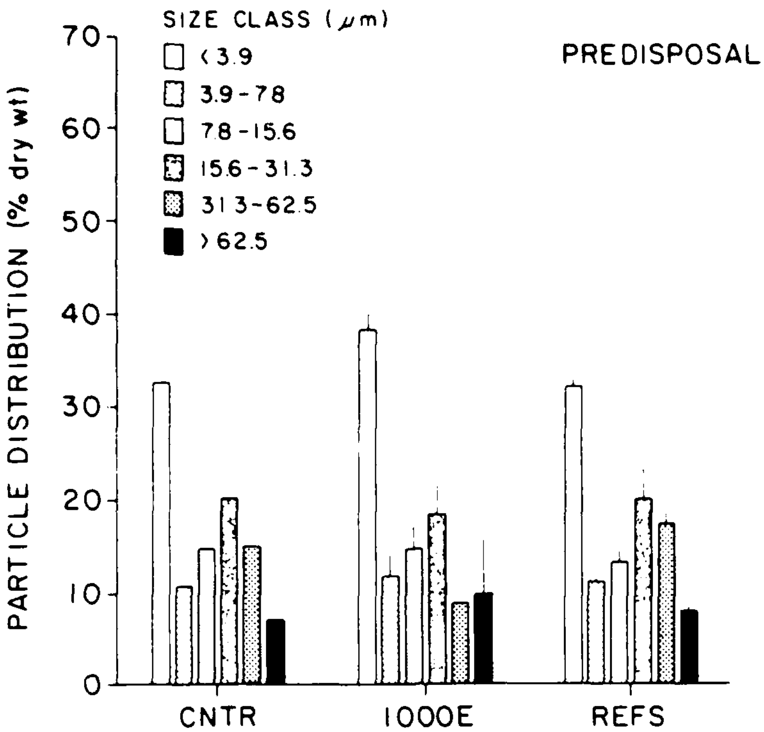


Figure 5. Grain-size particle distribution in surficial sediments at the FVP site, predisposal

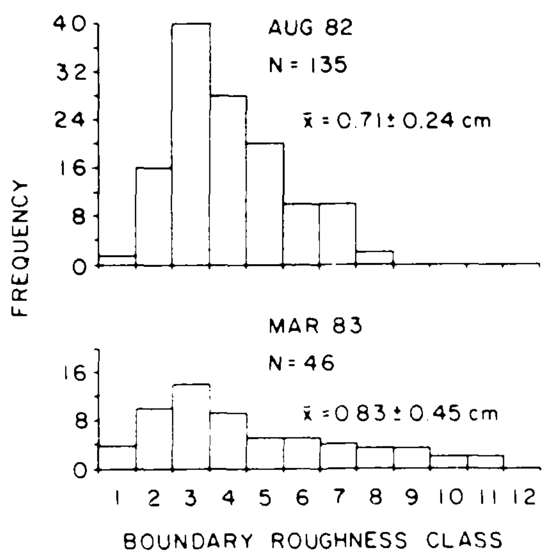


Figure 6. Predisposal frequency distributions for small-scale boundary roughness values at the FVP site in August 1982 and March 1983 as measured from REMOTS sediment-profile images. See Methods, Part II, for actual centimetre values of the designated classes

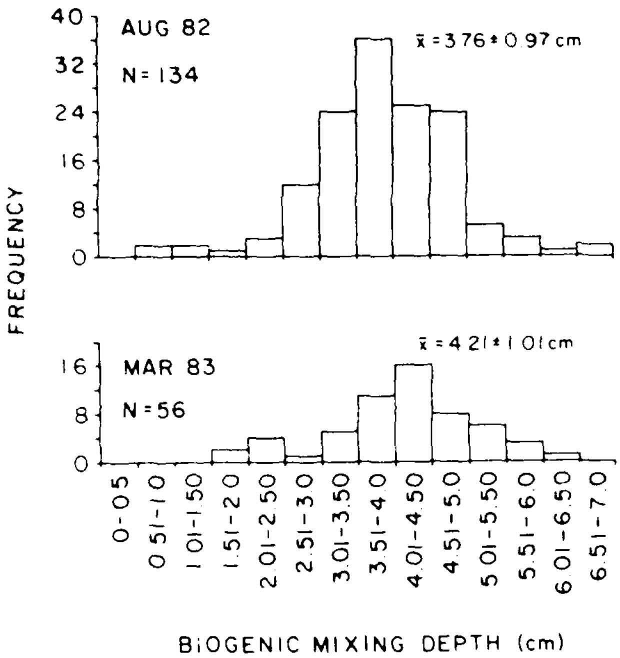


Figure 7. Predisposal frequency distributions for BMD at the FVP site in August 1982 and March 1983

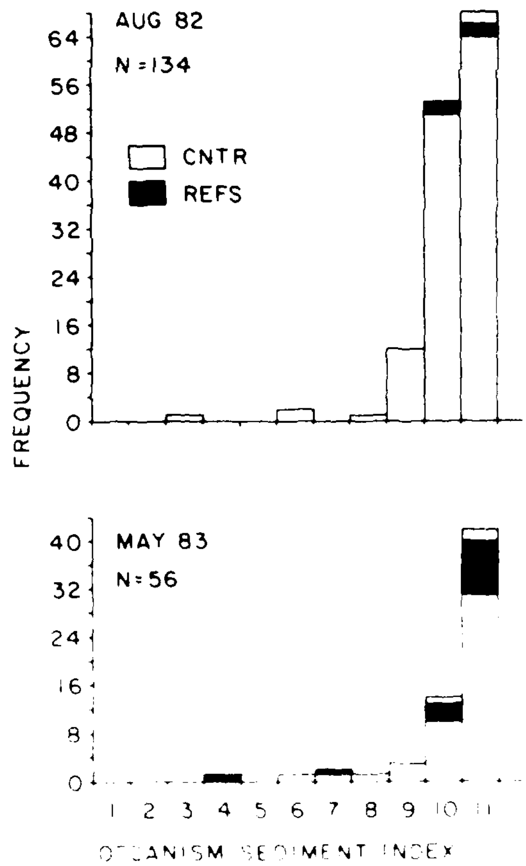


Figure 8. Predisposal frequency distributions of the OSIs at the FVP site and REFS in August 1982 and March 1983

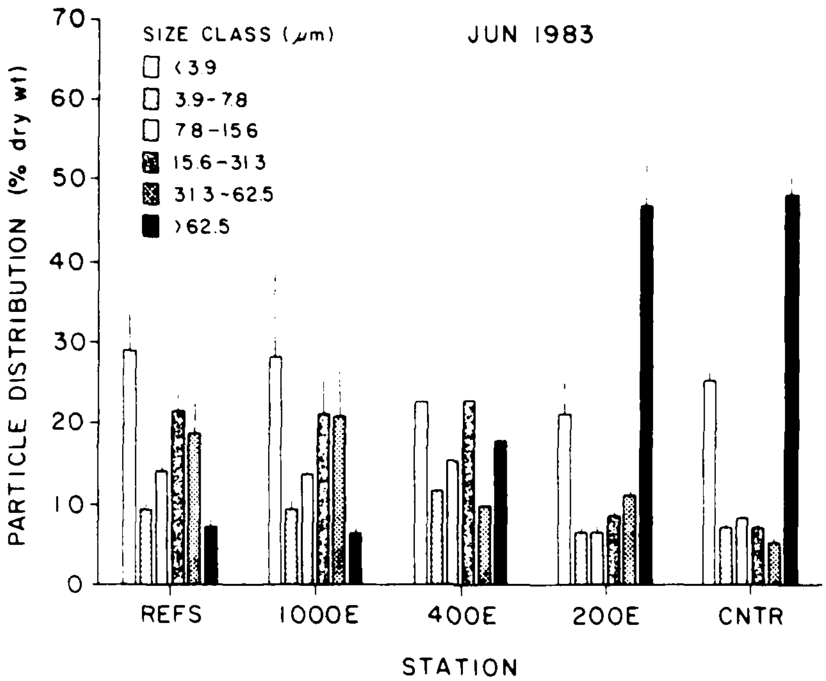


Figure 9. Grain-size particle distribution of surficial sediments at the FVP site in June 1983, immediately following disposal

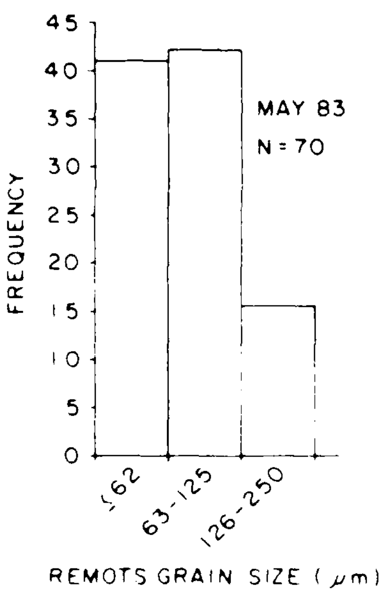
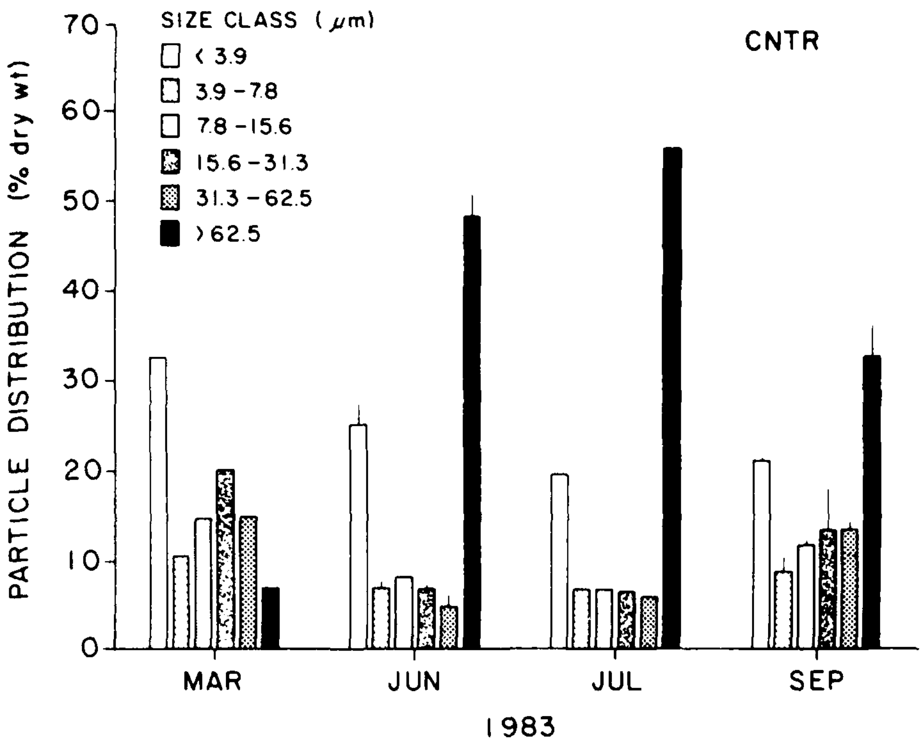
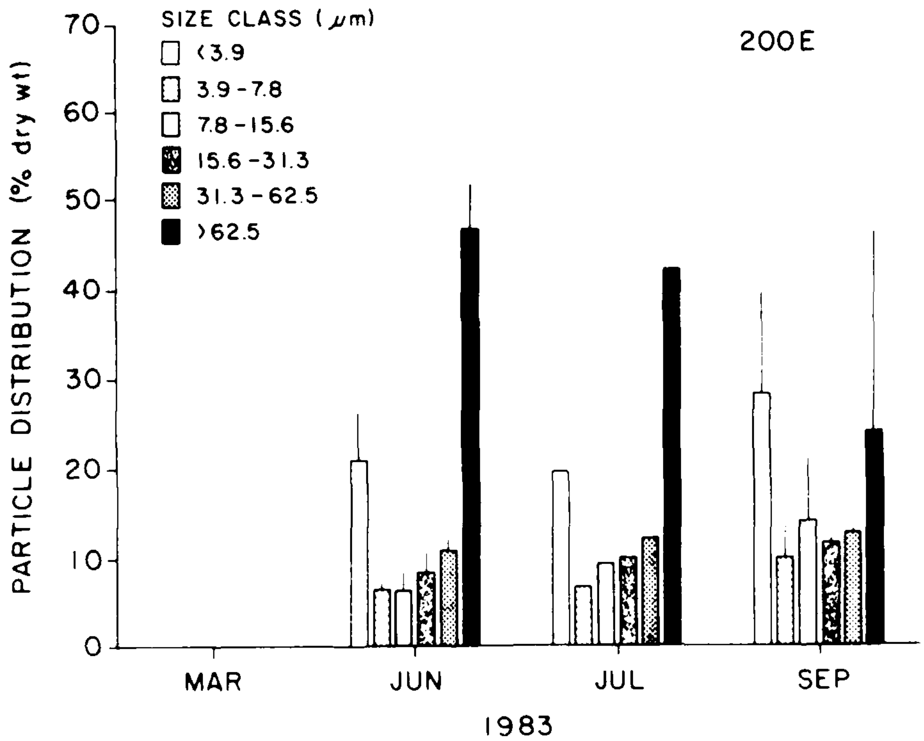


Figure 10. Postdisposal grain-size estimates made from REMOTS images, May 1983

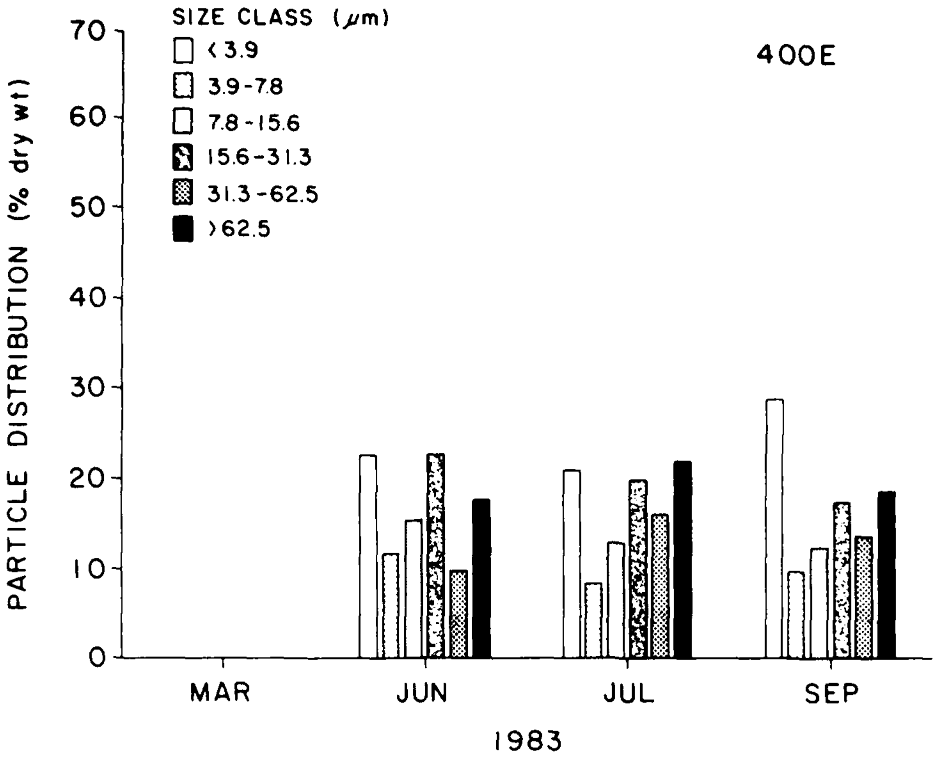


a. CNTR

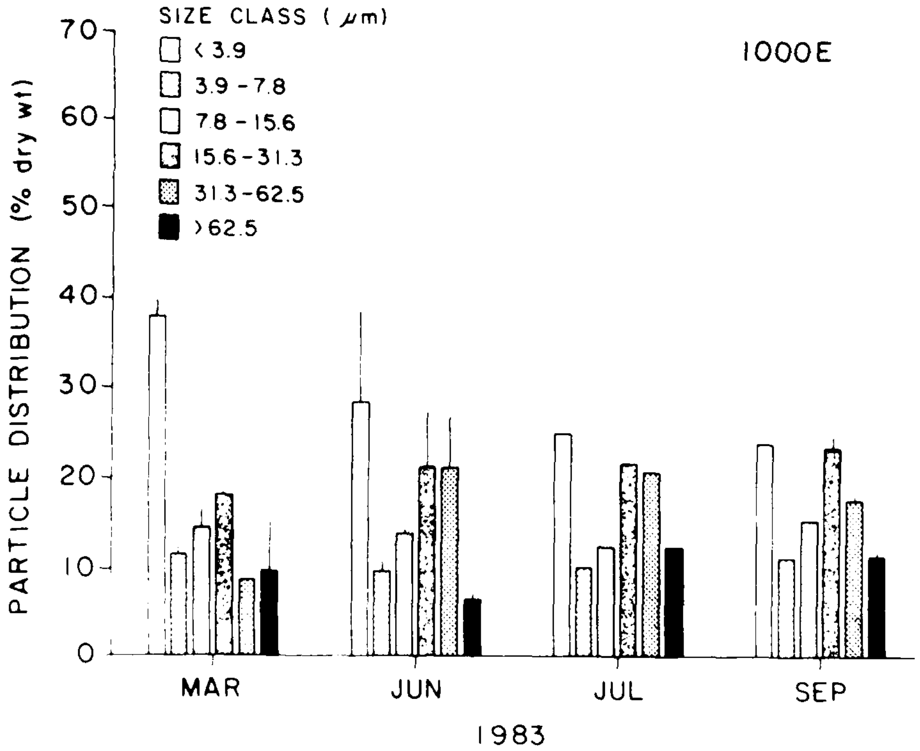


b. 200E

Figure 11. Grain-size particle distribution following disposal of BRH sediments (Sheet 1 of 3)

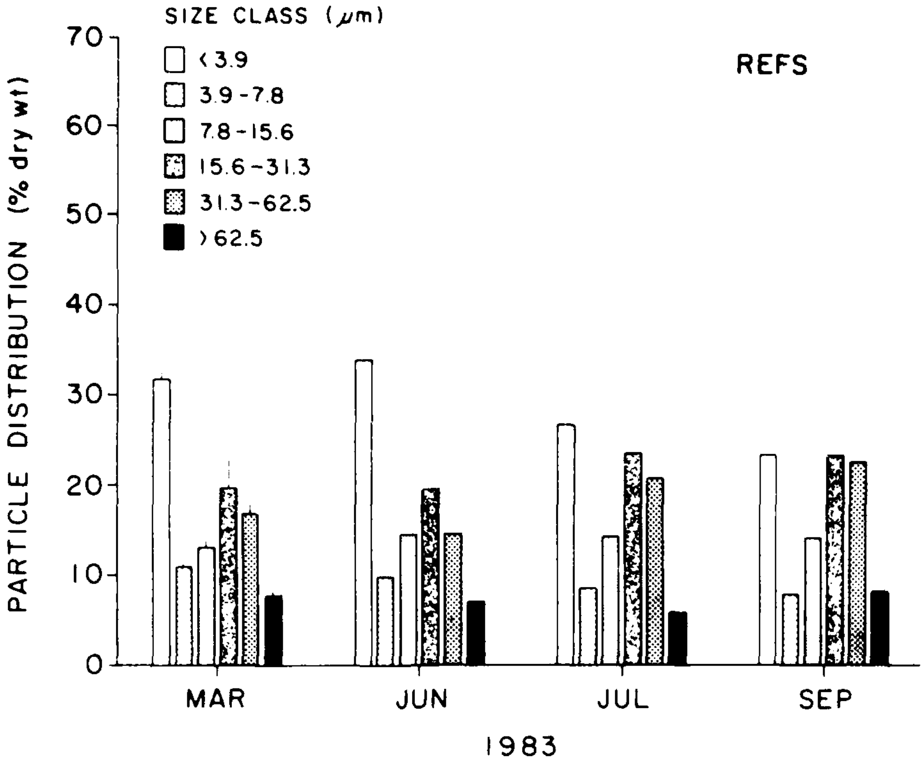


c. 400E



d. 1000E

Figure 11. (Sheet 2 of 3)



e. REFS

Figure 11. (Sheet 3 of 3)

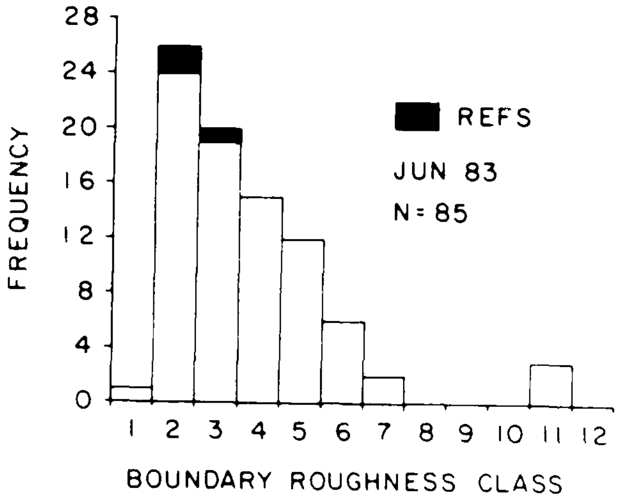


Figure 12. Distribution of boundary roughness value at FVP site in June 1983 as measured from REMOTS images

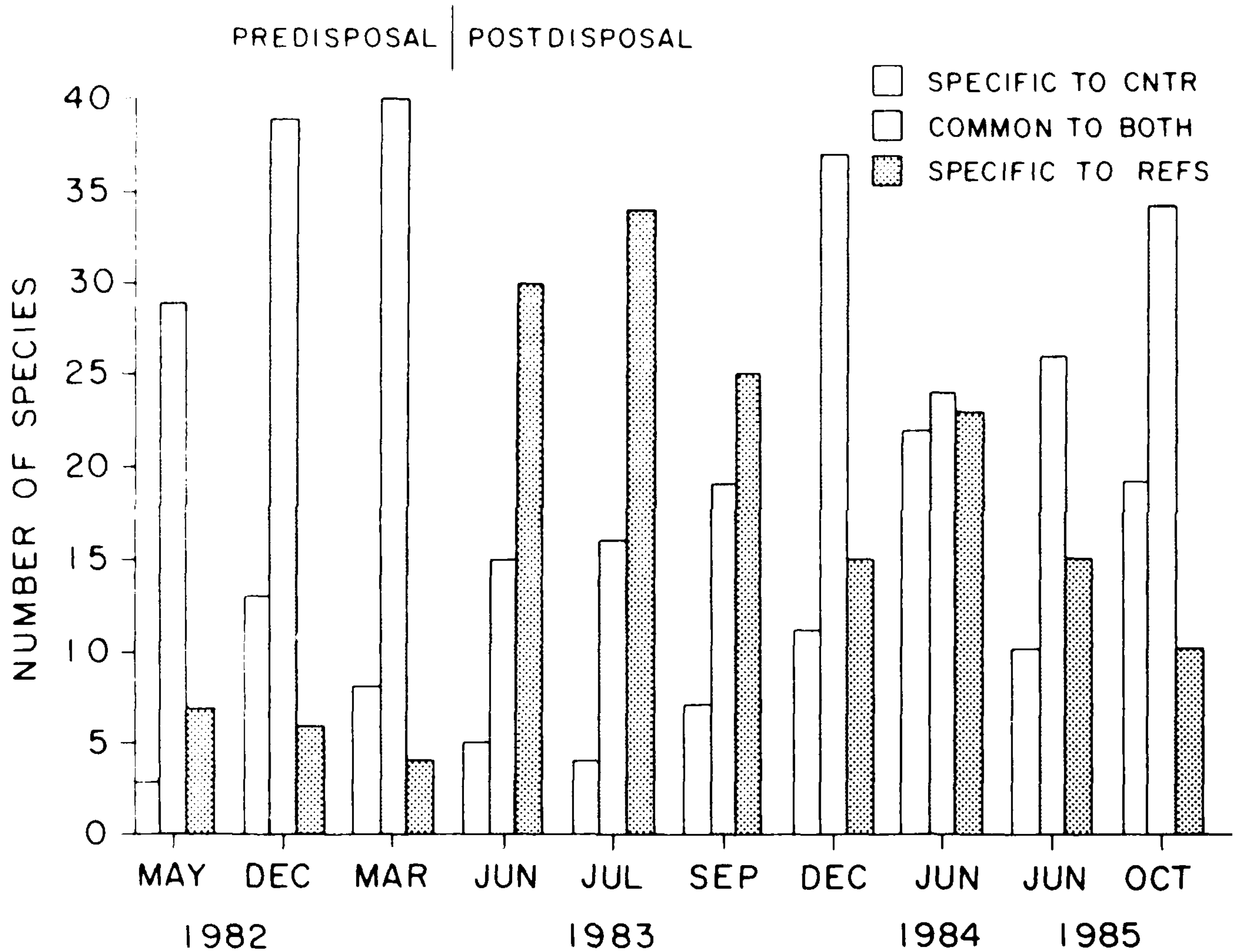
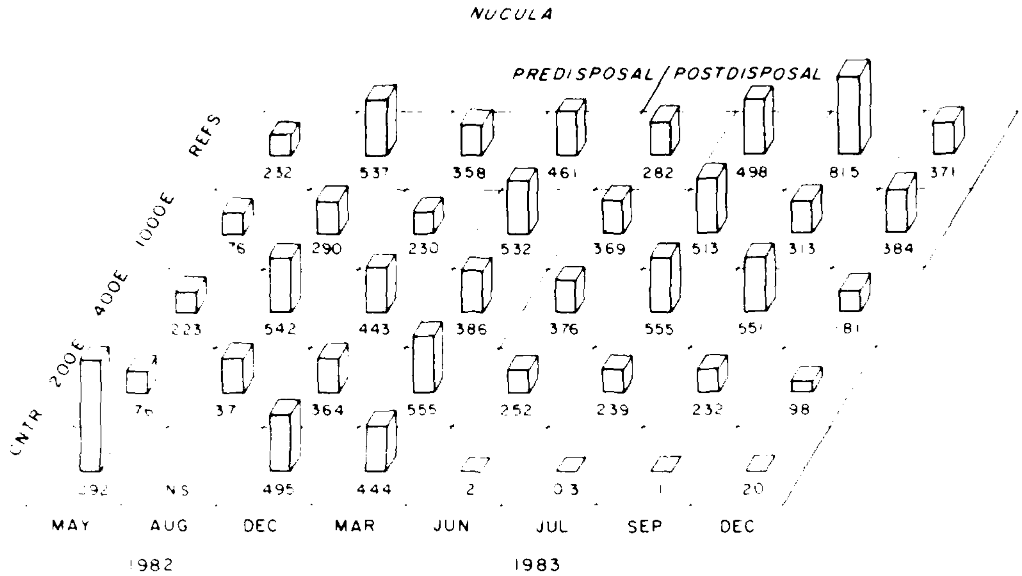
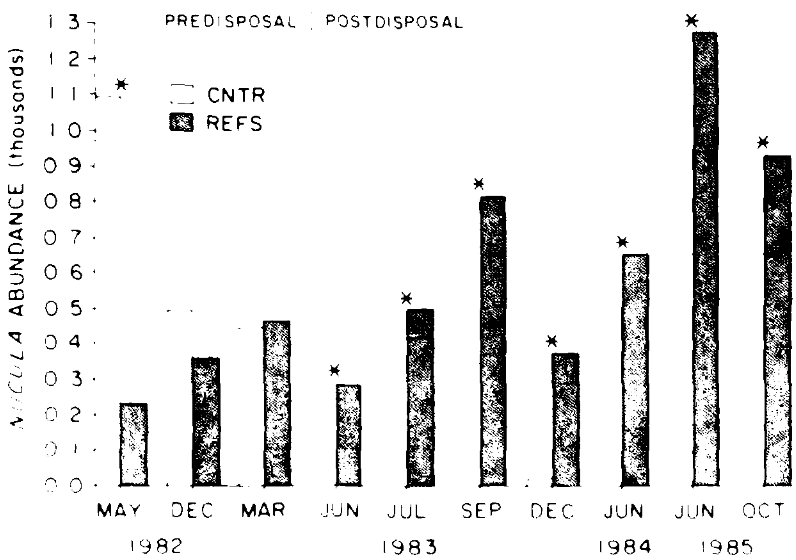


Figure 13. Numbers of species specific to CNTR and REFS and those common to both stations, May 1982 to October 1985

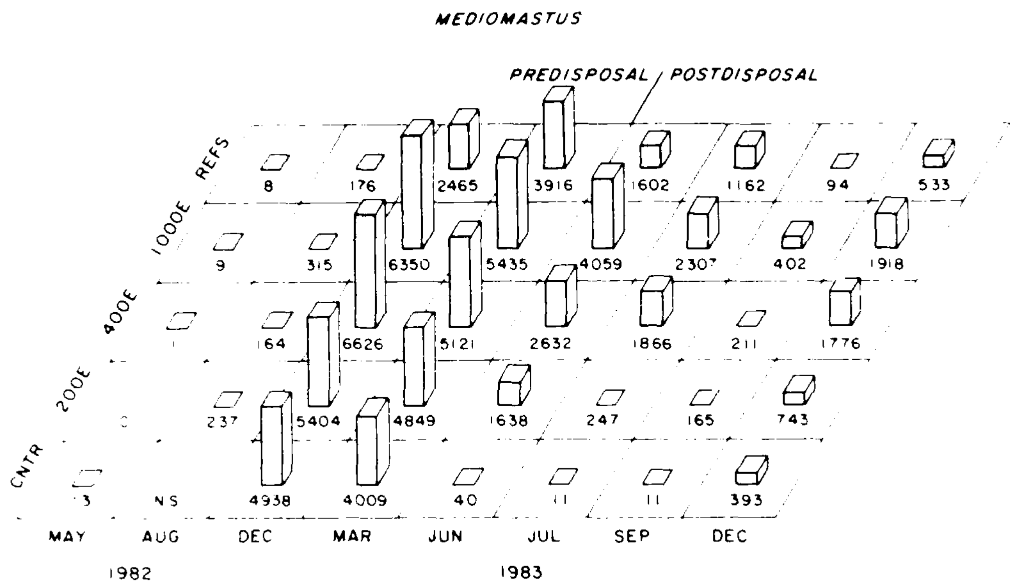


a. FVP site, May 1982 to December 1983

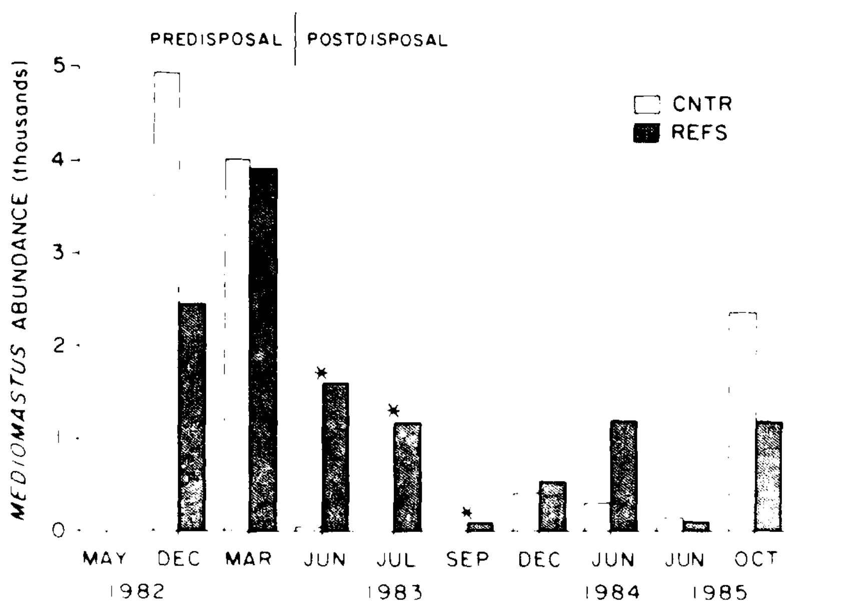


b. CNTR and REFS, May 1982 to October 1985

Figure [illegible]. Abundance of [illegible]. * Abundances are significantly different at P [illegible]



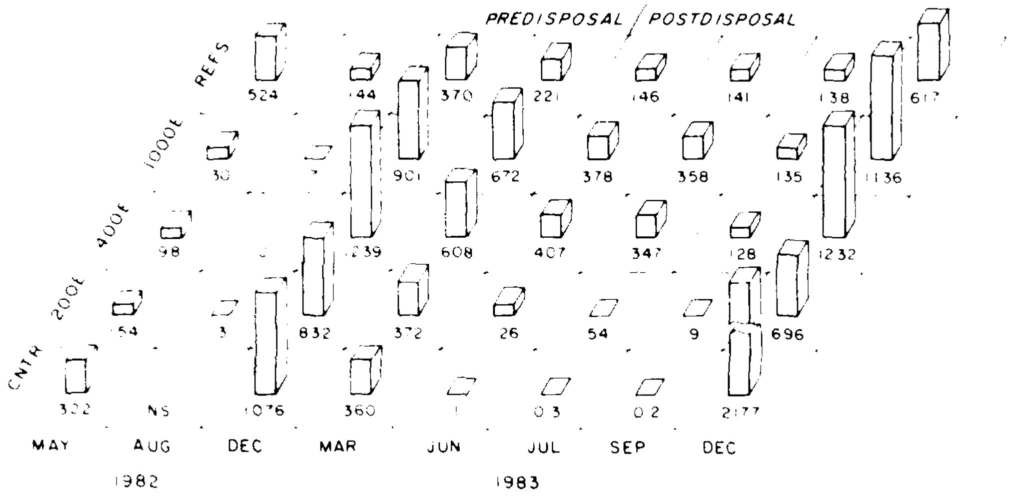
a. FVP site, May 1982 to December 1983



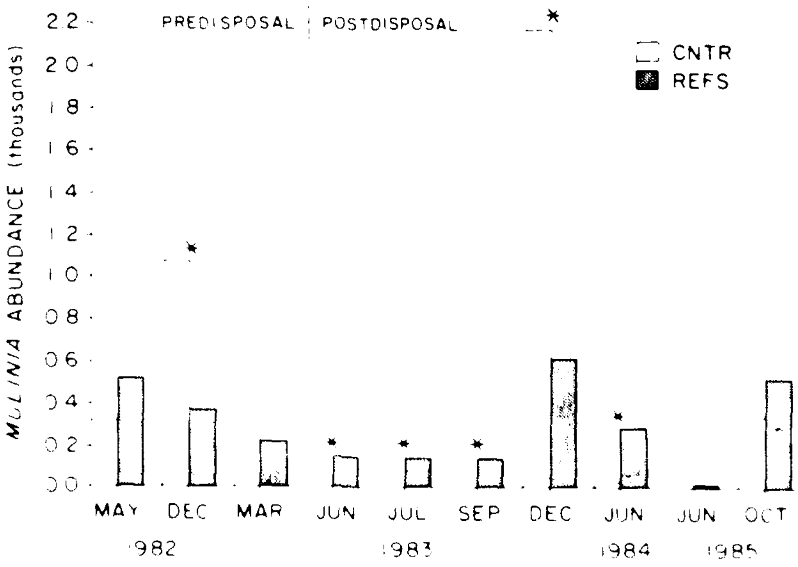
b. CNTR and REFS, May 1982 to October 1985

Figure 15. Abundance of [illegible] (* Abundances are significantly different at P < 0.05)

MULINIA

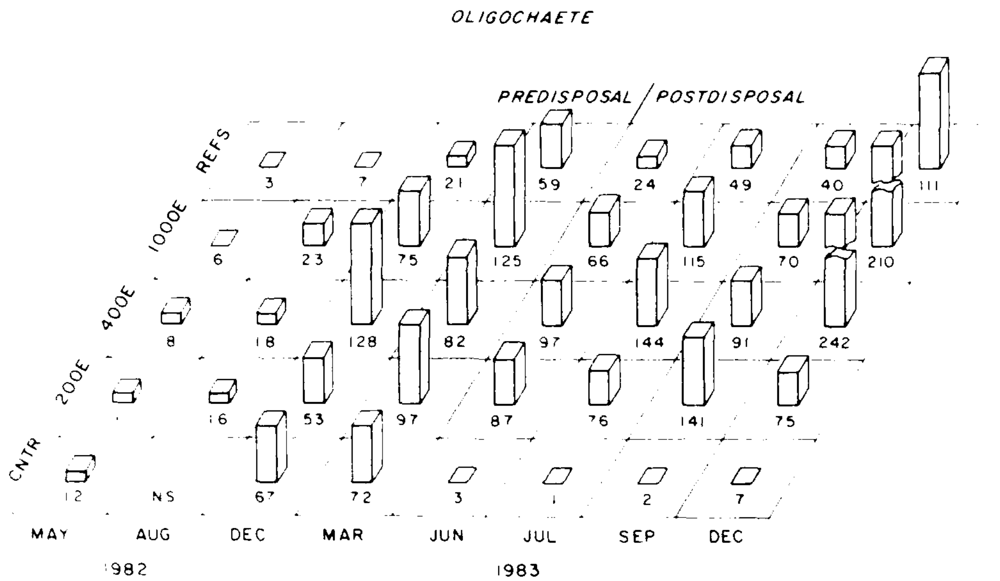


a. FVP site, May 1982 to December 1983

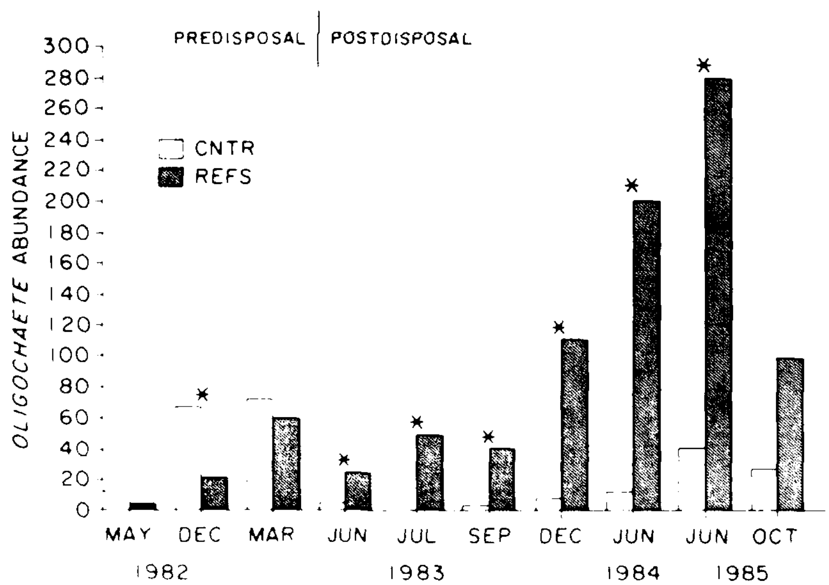


b. CNTR and REFS, May 1982 to October 1985

Figure [illegible]. Abundance of *Mulinia lateralis* (★ Abundances are significantly different at P < 0.05)

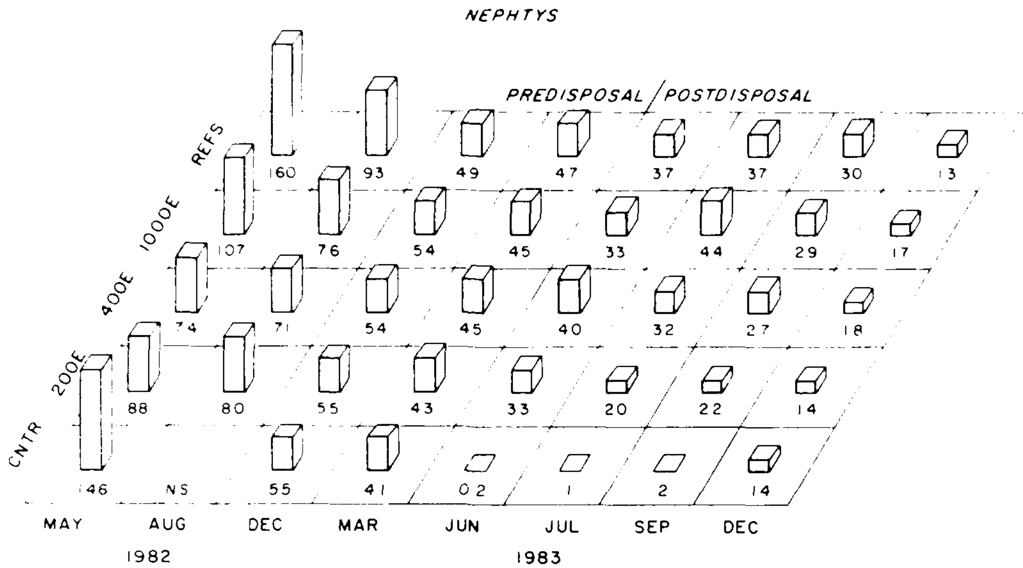


a. FVP site, May 1982 to December 1983

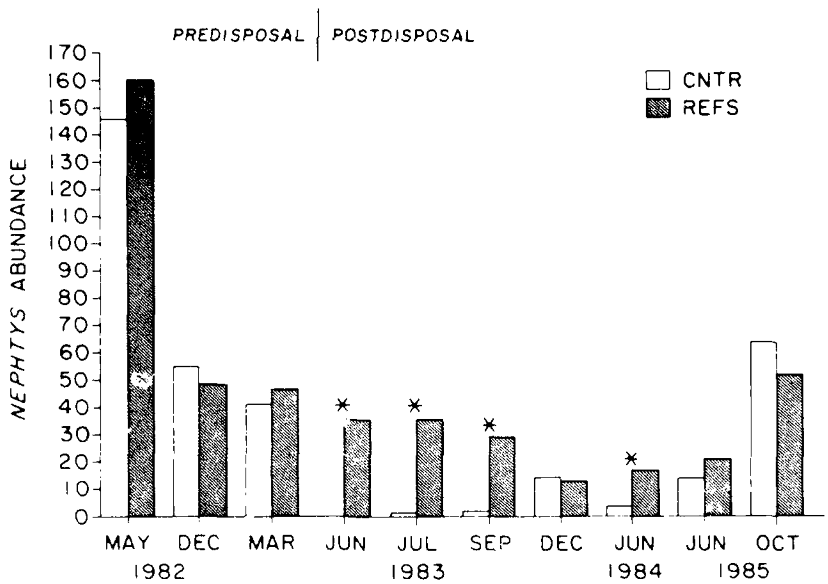


b. CNTR and REFS, May 1982 to October 1985

Figure 17. Abundance of [illegible] sp. (* Abundances are significantly different at P ≤ 0.05)

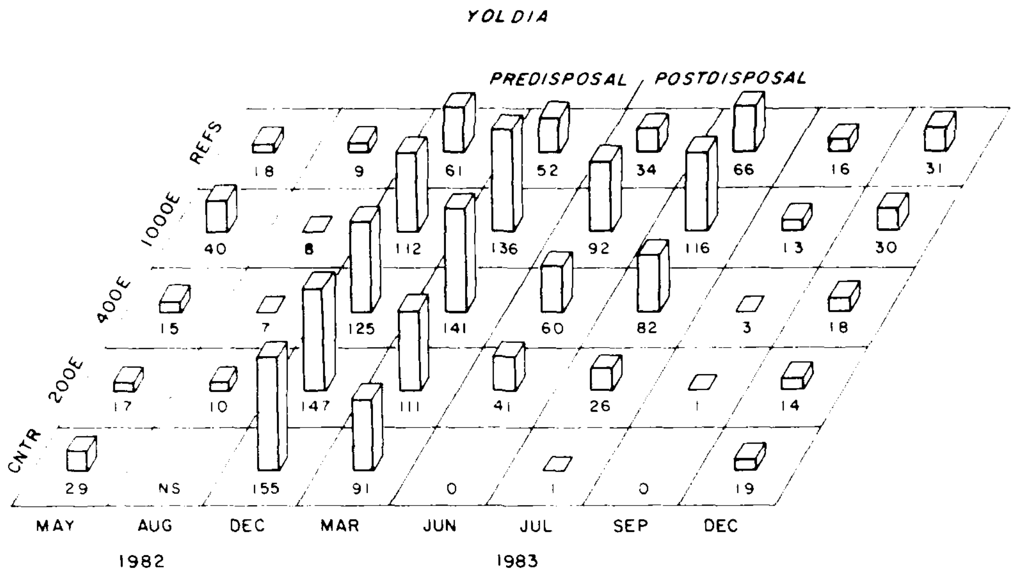


a. FVP site, May 1982 to December 1983

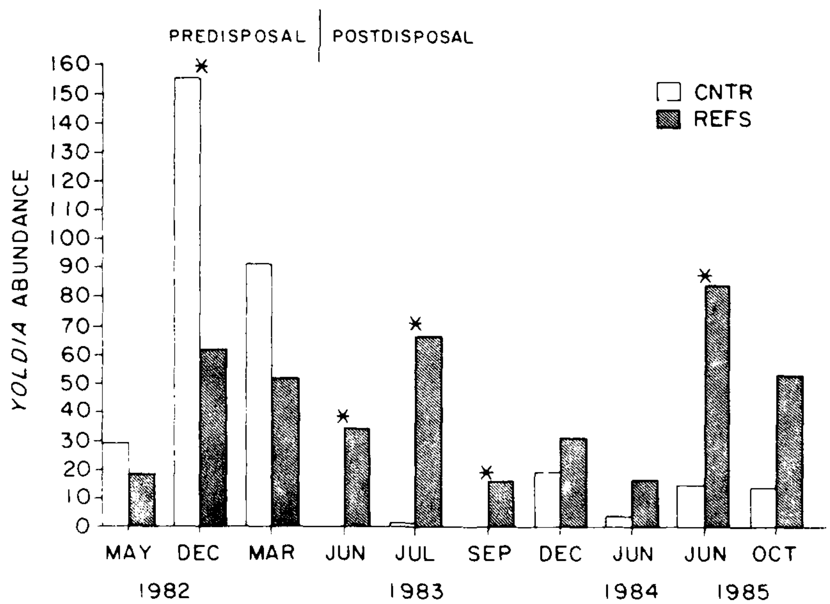


b. CNTR and REFS, May 1982 to October 1985

Figure 18. Abundance of *Nephtys incisa* (* Abundances are significantly different at P > 0.05)

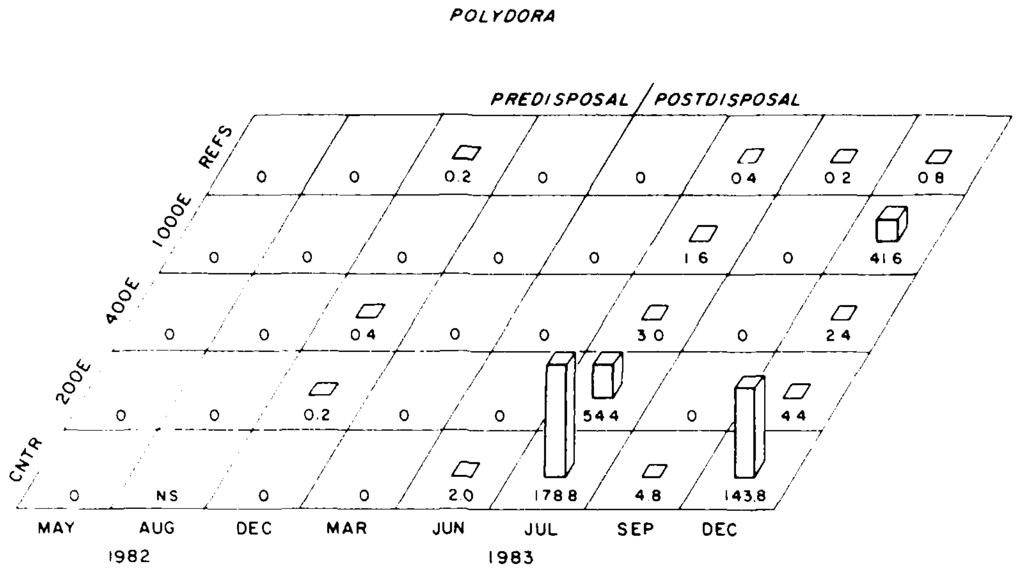


a. FVP site, May 1982 to December 1983

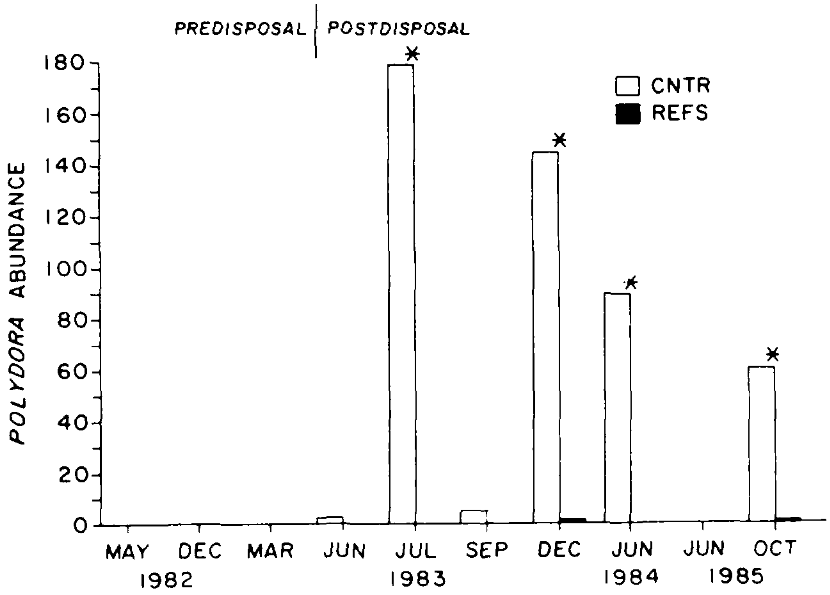


b. CNTR and REFS, May 1982 to October 1985

Figure 19. Abundance of *Yoldia limatula* (* Abundances are significantly different at $P > 0.05$)

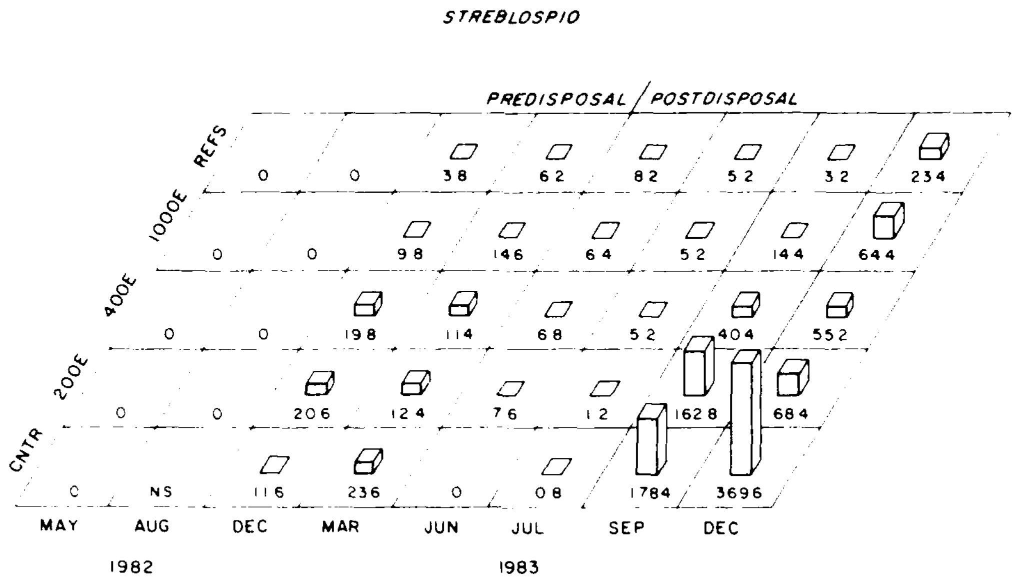


a. FVP site, May 1982 to December 1982

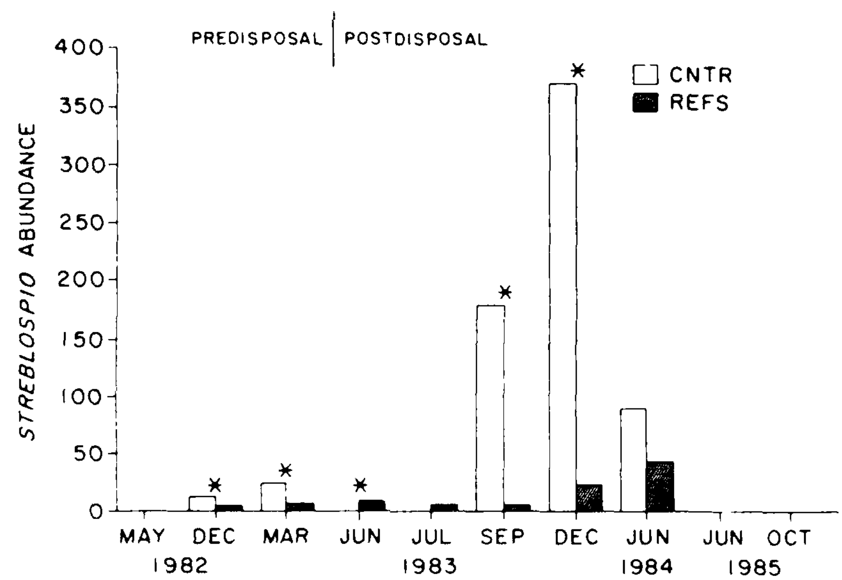


b. CNTR and REFS, May 1982 to October 1985

Figure 20. Abundance of *Polydora ligni* (* Abundances are significantly different at P > 0.05)

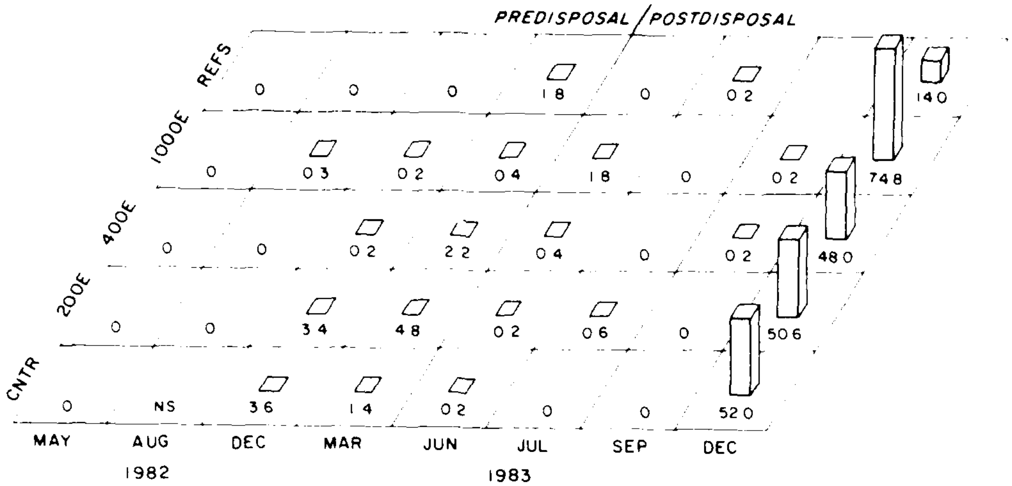


a. FVP site, May 1982 to December 1982

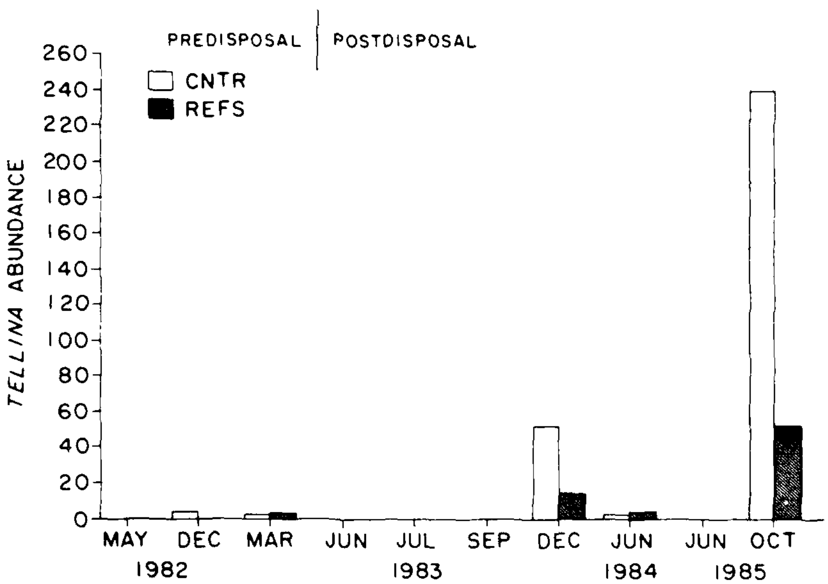


b. CNTR and REFS, May 1982 to October 1985

Figure 21. Abundance of *Streblospio benedicti* (* Abundances are significantly different at P > 0.05)



a. FVP site, May 1982 to December 1983



b. CNTR and REFS, May 1982 to October 1985

Figure 22. Abundance of *Tellina agilis* (* Abundances are significantly different at P > 0.05)

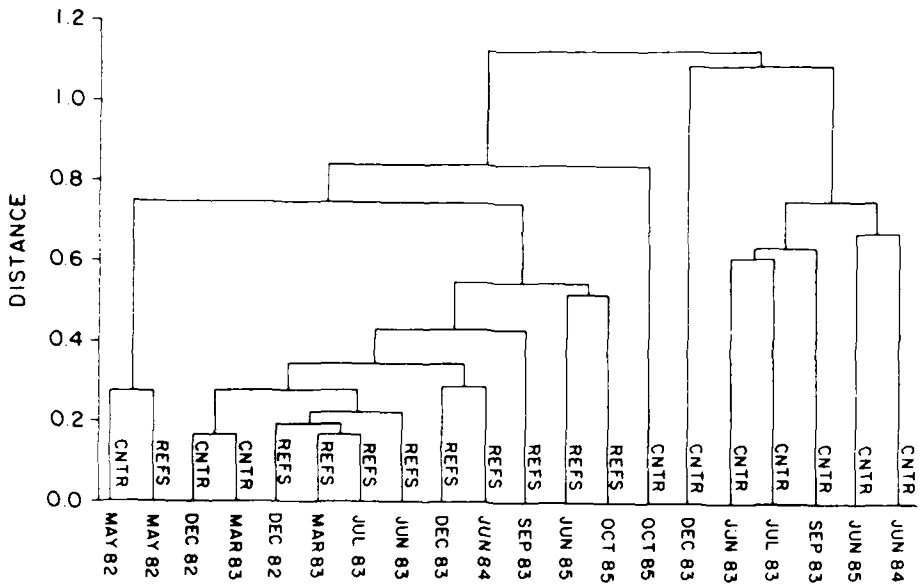


Figure 23. Hierarchical cluster analysis based on dominant species abundances for the CNTR and REFS stations, May 1982 to October 1985

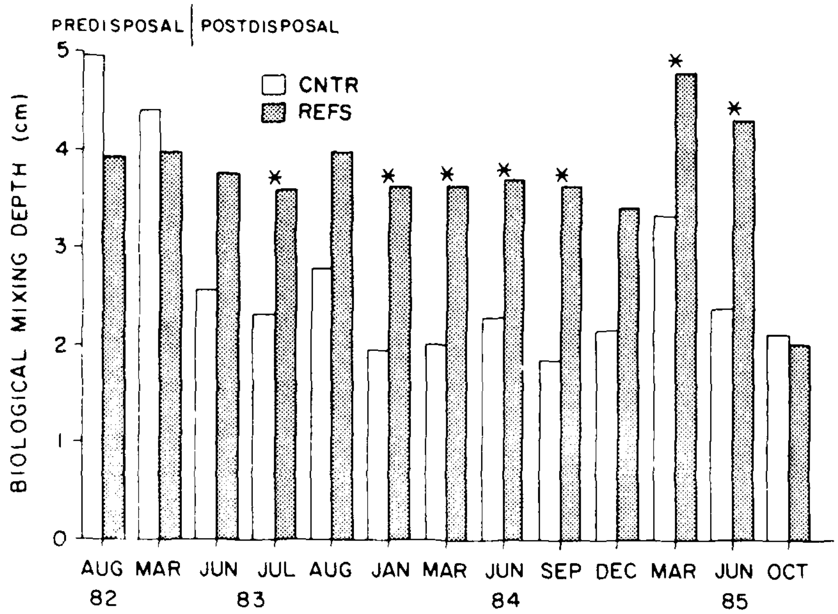
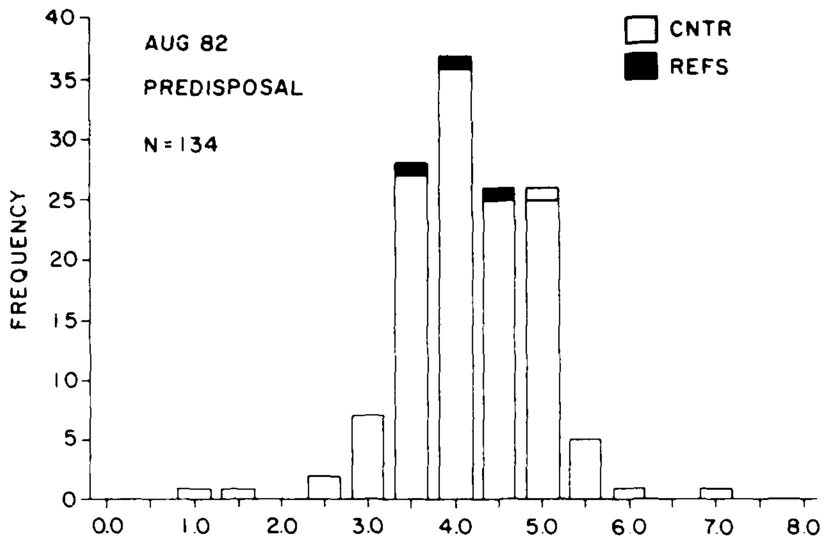
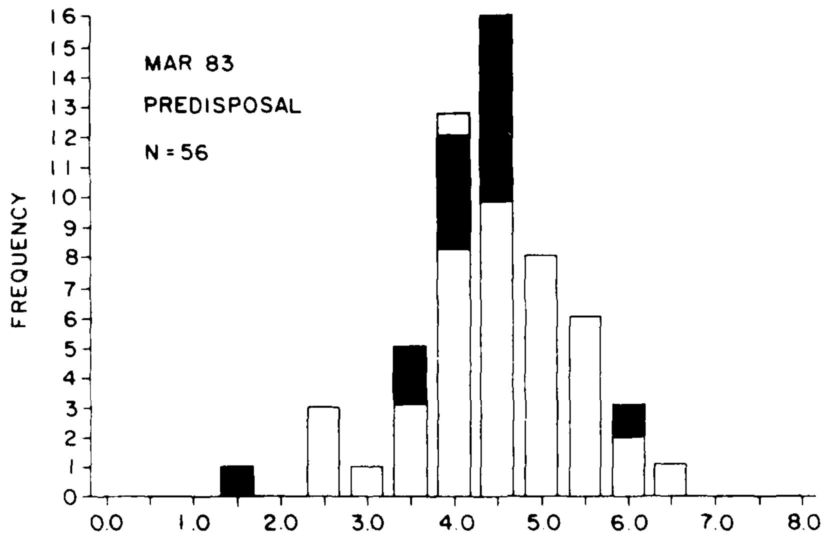


Figure 24. Mean biological mixing depths (*BMD*) at CNTR and REFS August 1982 to October 1985 (* indicates significant differences at $P > 0.05$)

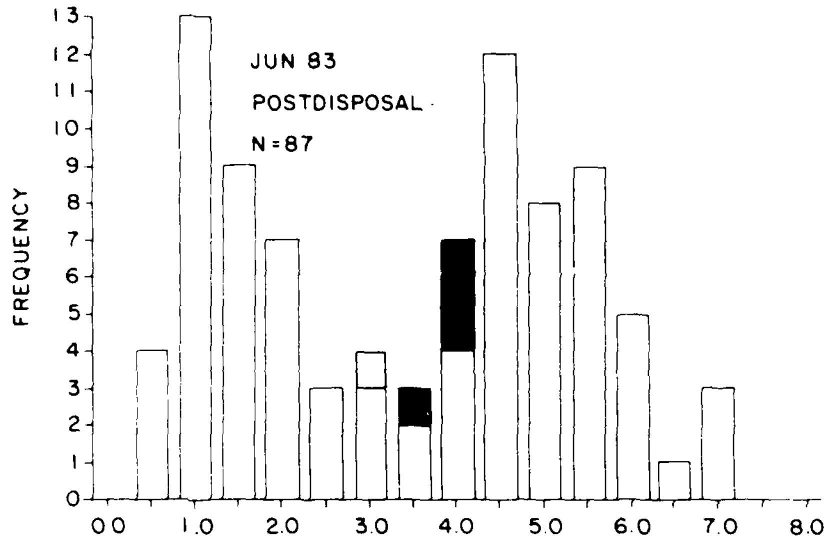


a. August 1982

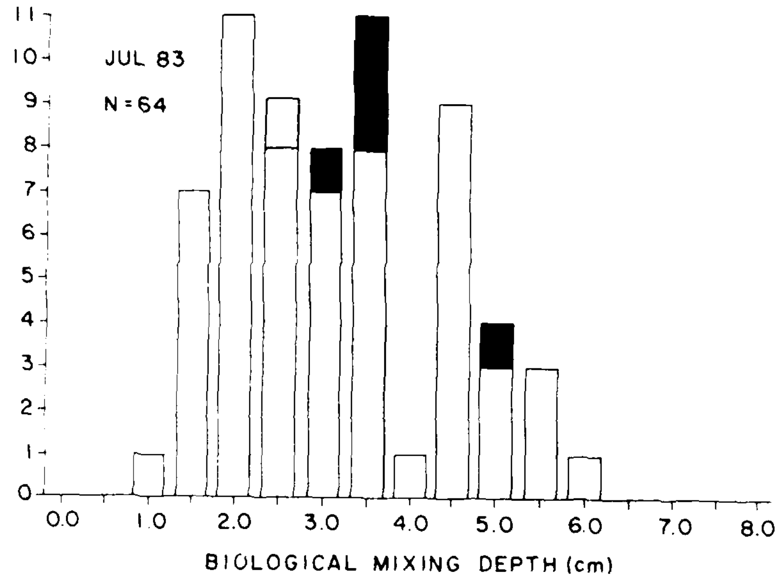


b. March 1983

Figure 25. Postdisposal frequency distributions of BMDs, centimetres, at the FVP site from June 1983 to October 1985 (Sheet 1 of 6)

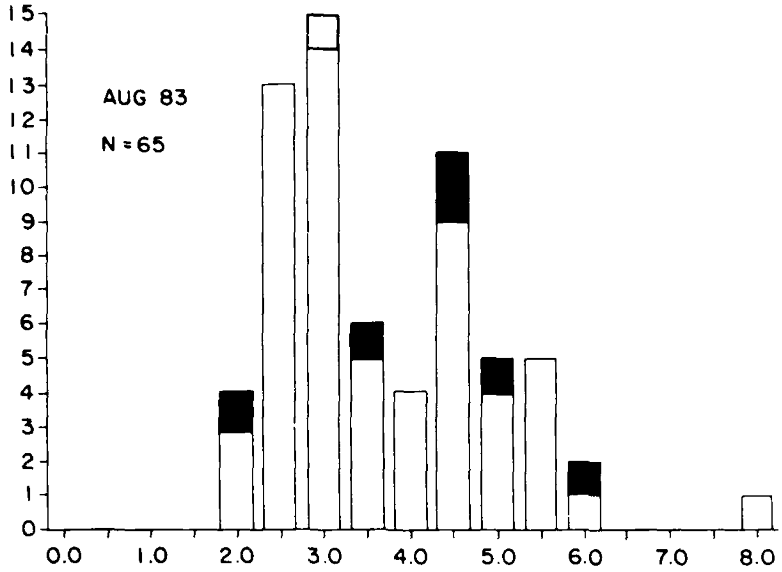


c. June 1983

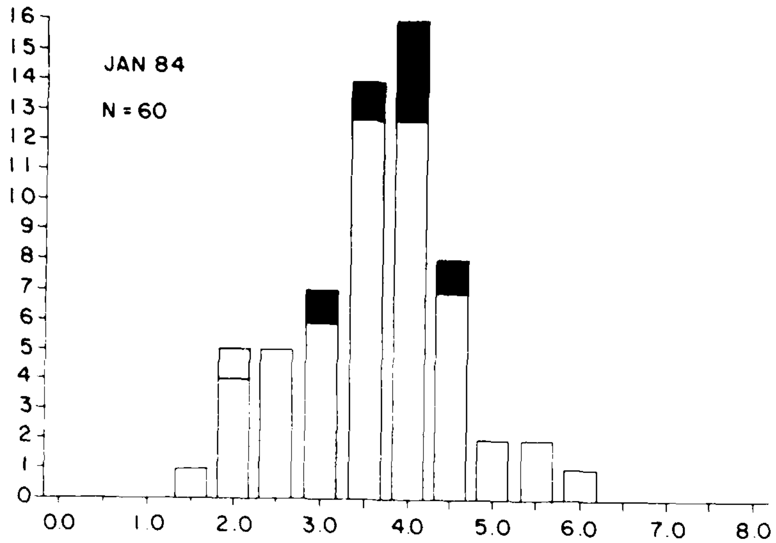


d. July 1983

Figure 25. (Sheet 2 of 6)

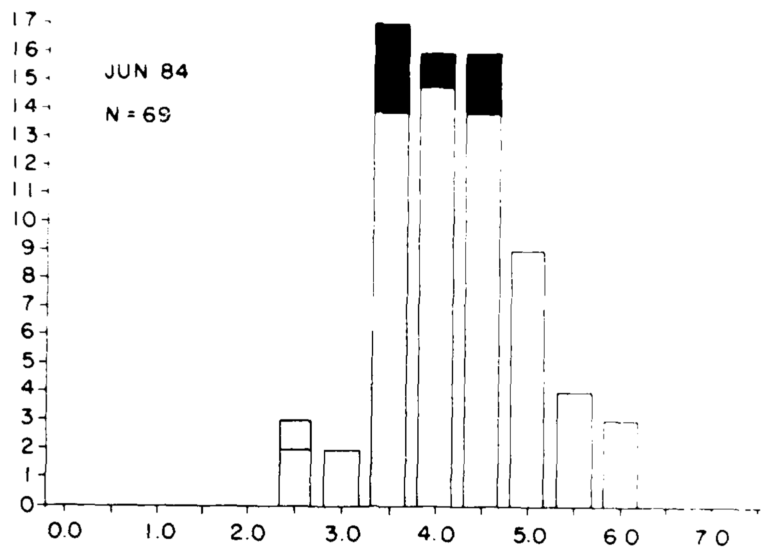


e. August 1983

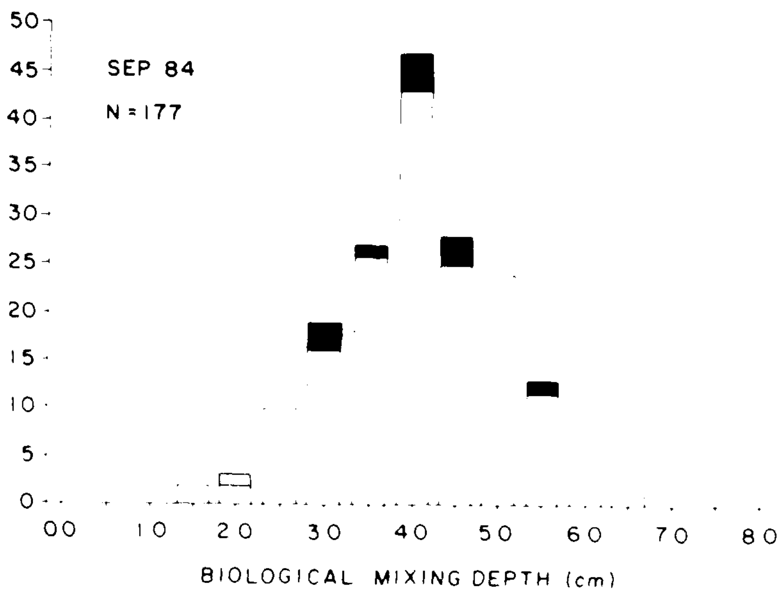


f. January 1984

Figure 25. (Sheet 3 of 6)

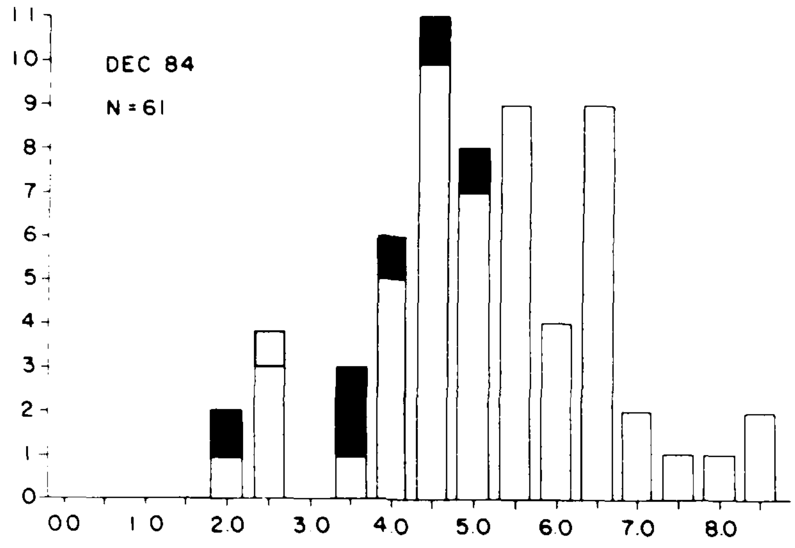


g. June 1984

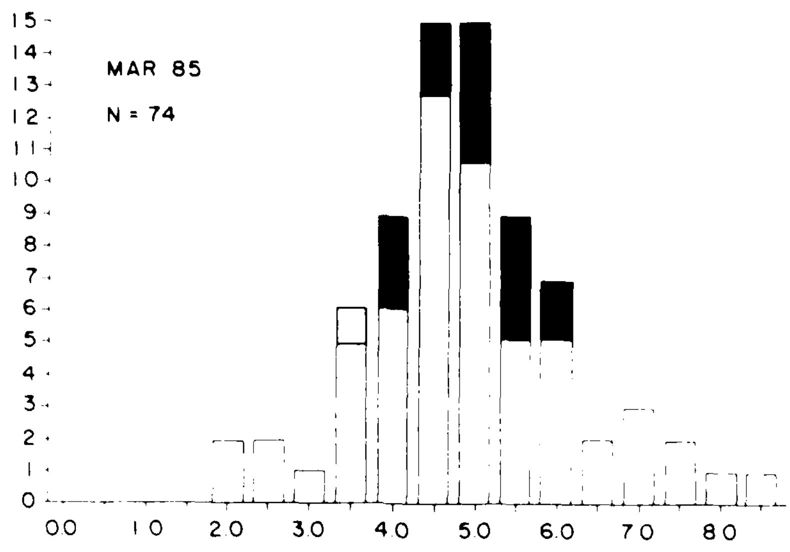


h. September 1984

Figure 25. (Sheet 4 of 6)

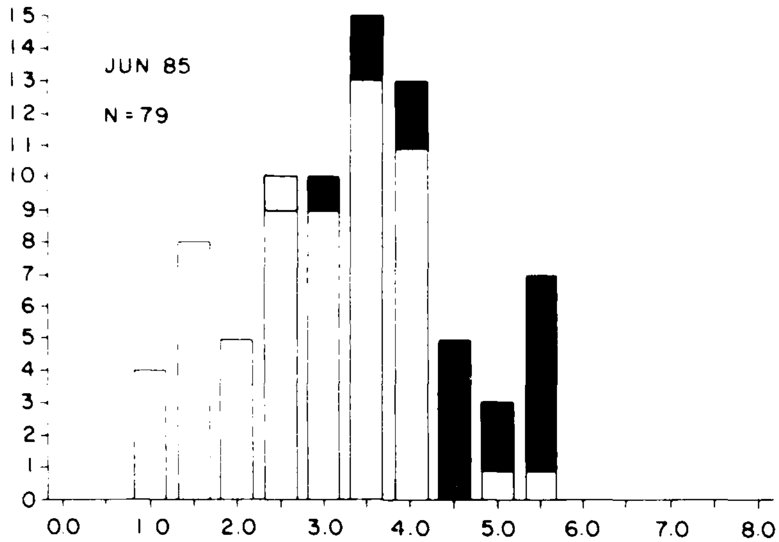


i. December 1984

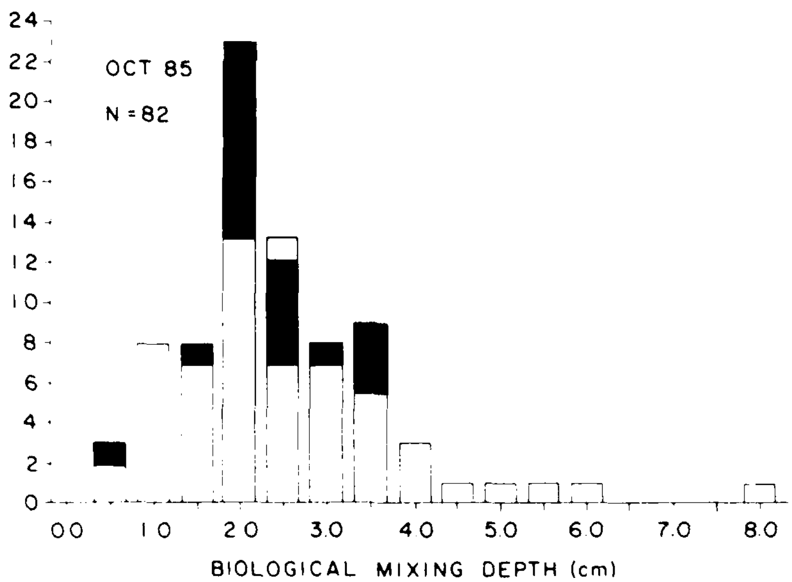


j. March 1985

Figure 25. (Sheet 5 of 6)



k. June 1985



l. October 1985

Figure 25. (Sheet 6 of 6)

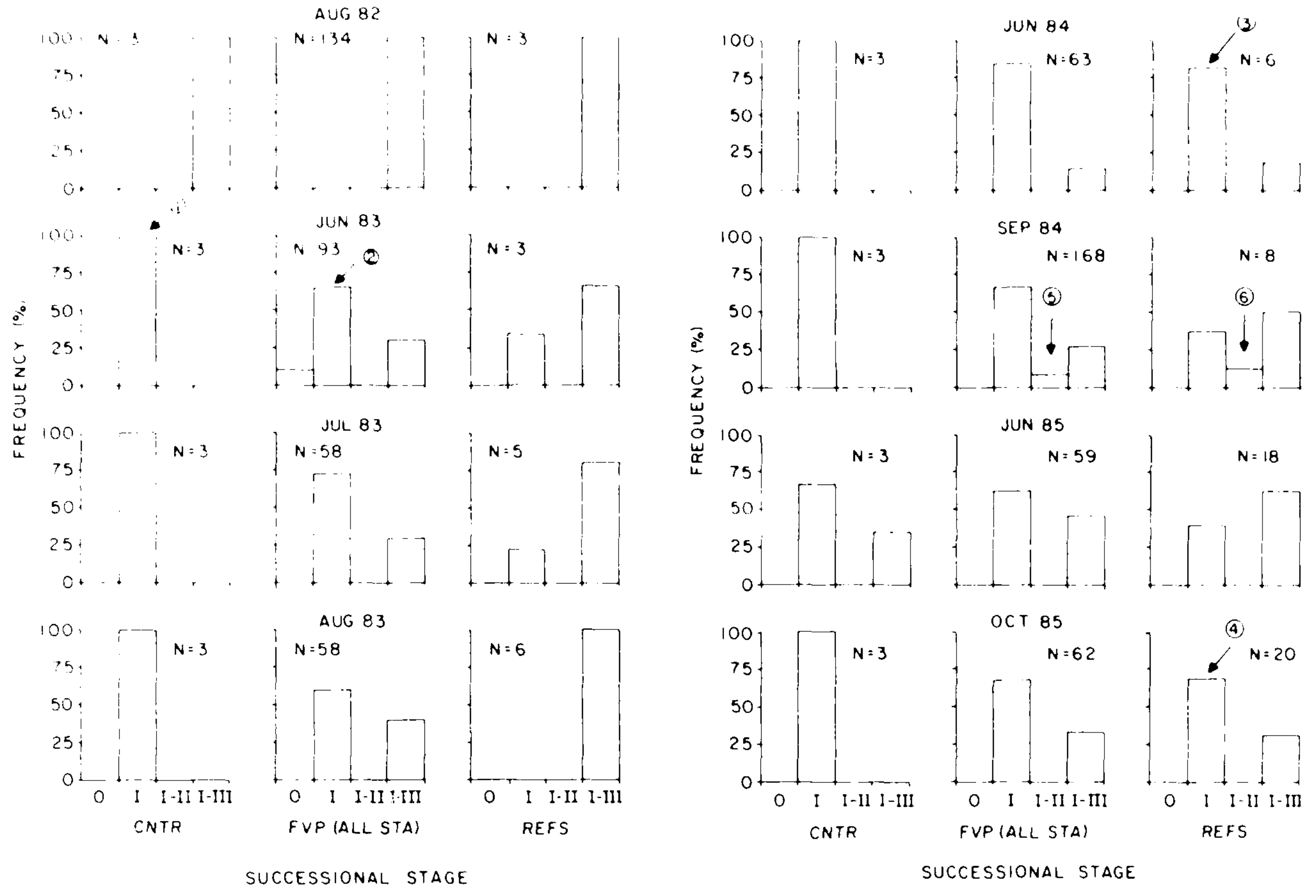


Figure 26. Predisposal and postdisposal frequency of successional stages. Data plotted separately for CNTR, overall FVP site (including CNTR), and South REFS. Data plotted for "warm-water" survey dates only. Arrows (1 and 2) = shift in successional status from I-III seres to a Stage I pioneering following the disposal operation, (3) = retrograde succession at South REFS attributed to intensive sampling of the site, (4) = retrograde succession at South REFS attributed to Hurricane Gloria, (5 and 6) = appearance of tubicolous amphipods

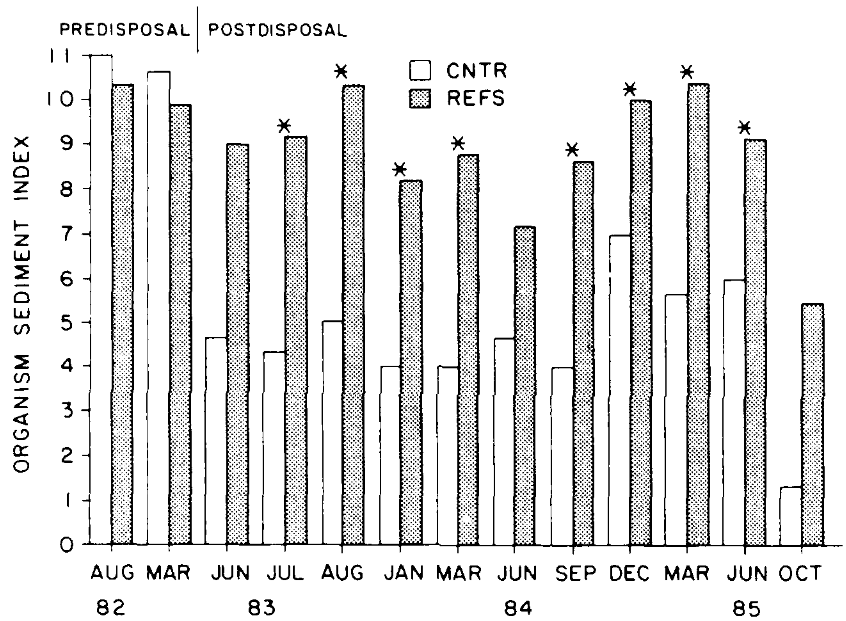
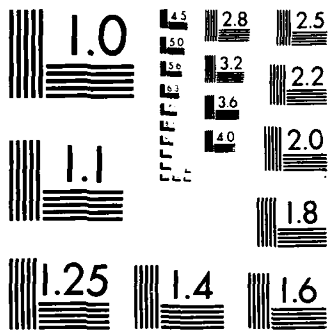


Figure 27. Mean OSIs at CNTR and REFS from August 1982 to October 1985 (* indicates significant station differences at P > 0.05)

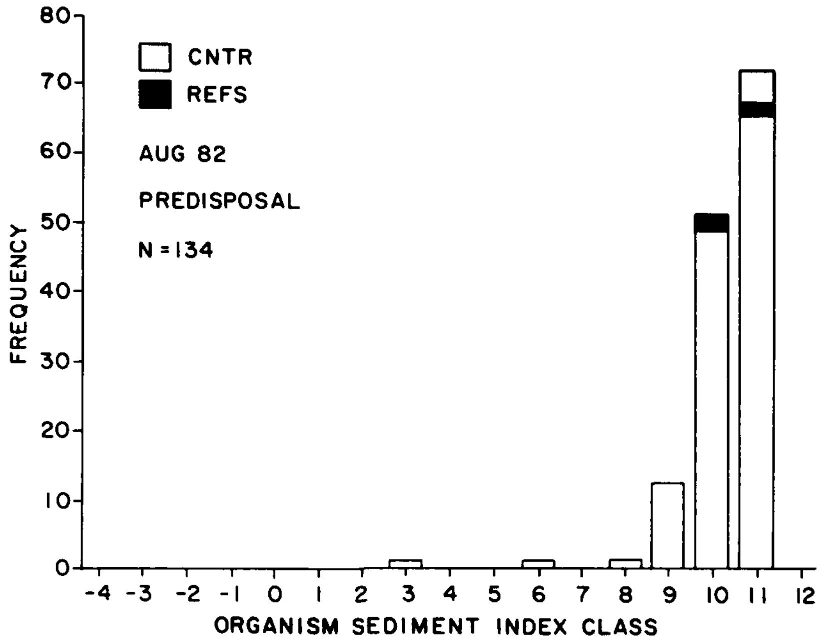
AD-A184 166 FIELD VERIFICATION PROGRAM (AQUATIC DISPOSAL) IMPACT OF OPEN-WATER DISPOS (U) SCIENCE APPLICATIONS INTERNATIONAL CORP NARRAGANSETT RI J SCOTT ET AL JUL 87 WES/TR/D-87-4 2/2

UNCLASSIFIED F/G 24/4 NL

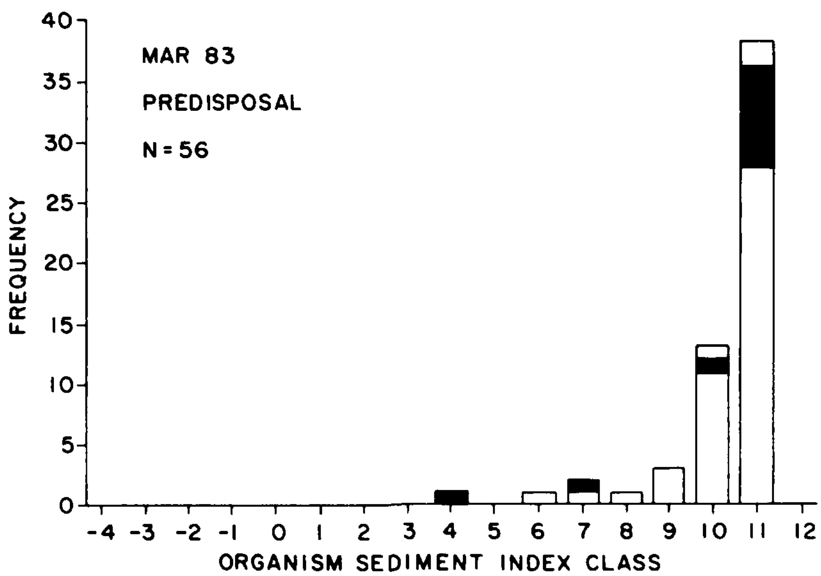
END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

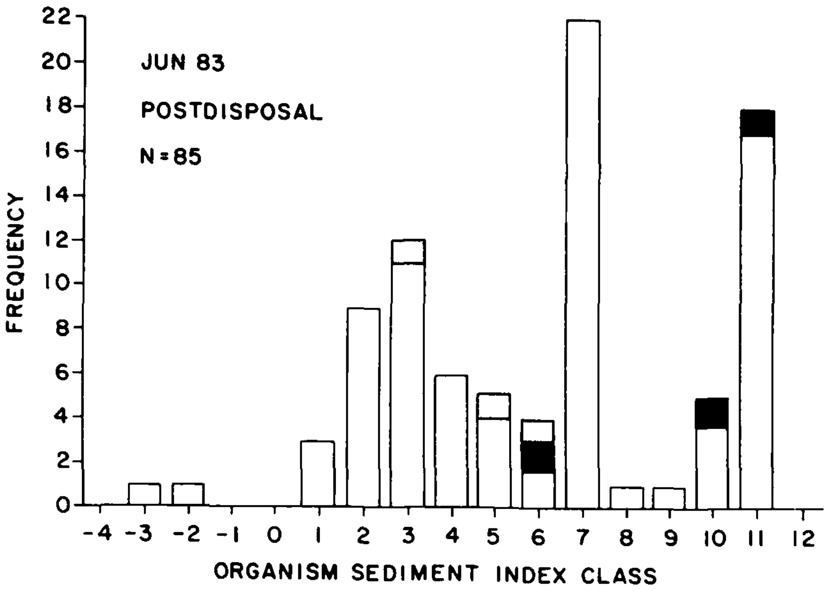


a. August 1982

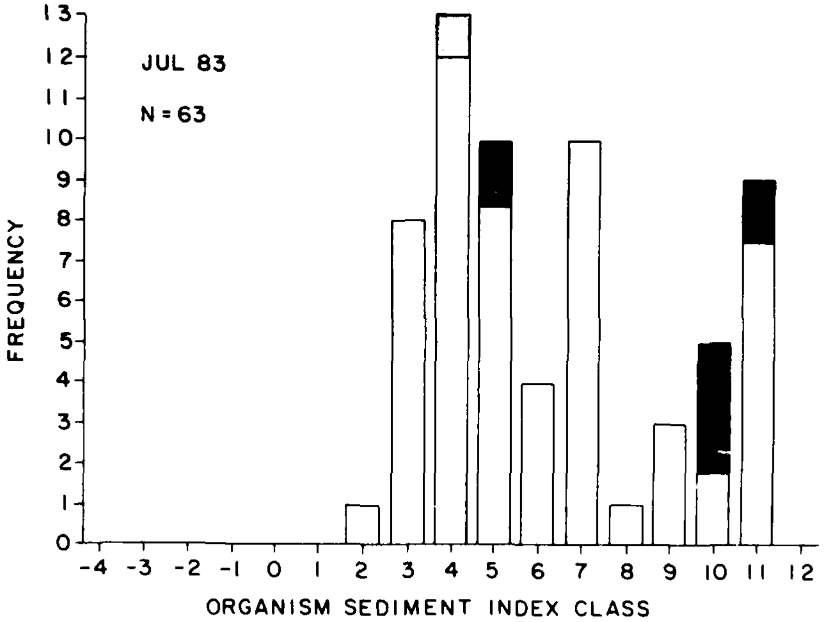


b. March 1983

Figure 28. Postdisposal frequency distributions of OSIs at the FVP site from June 1983 to October 1985 (Sheet 1 of 6)

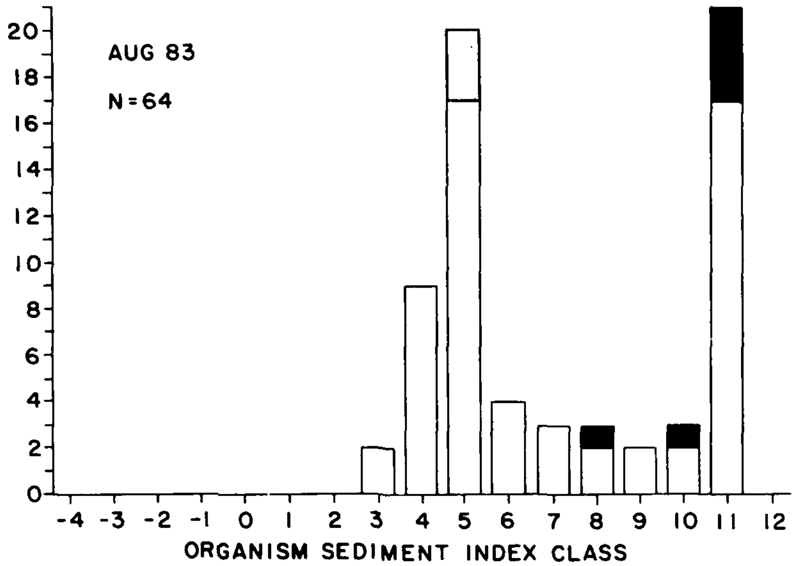


c. June 1983

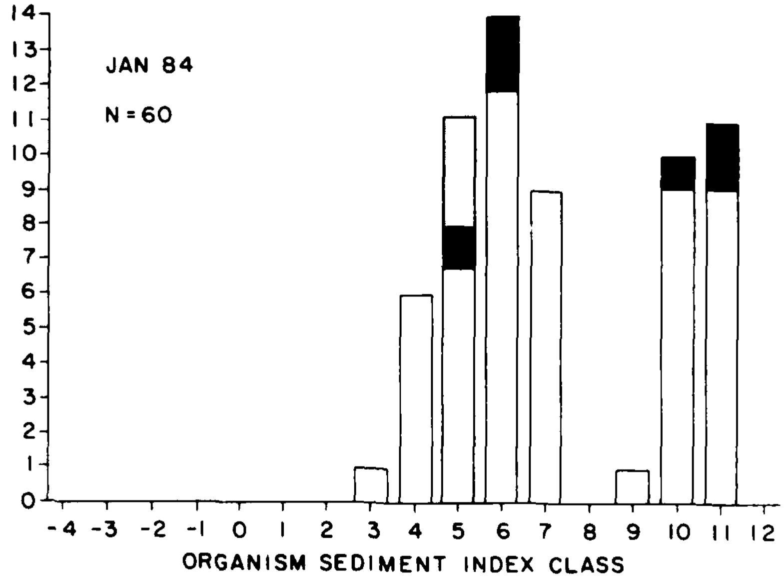


d. July 1983

Figure 28. (Sheet 2 of 6)

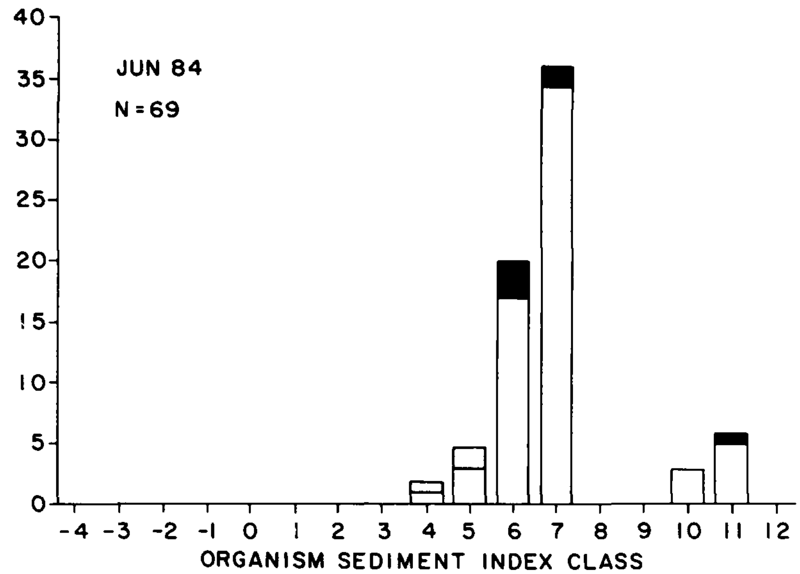


e. August 1983

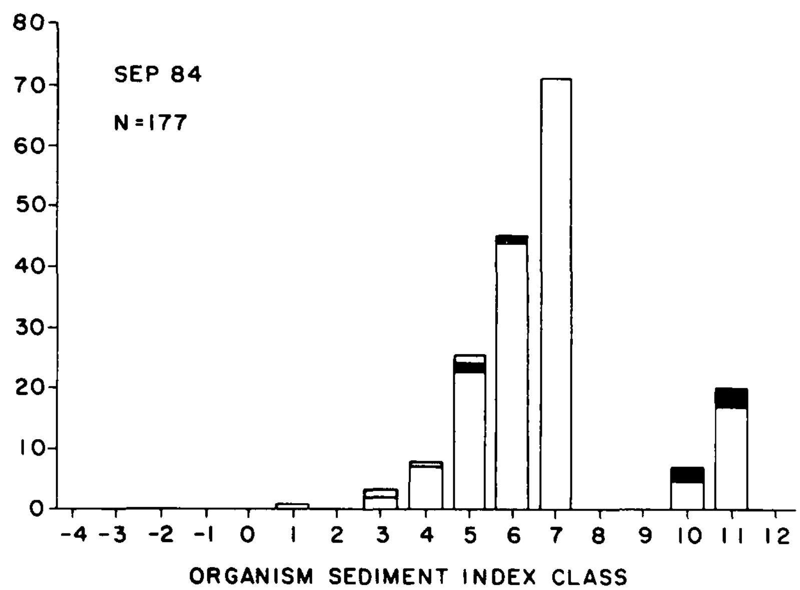


f. January 1984

Figure 28. (Sheet 3 of 6)

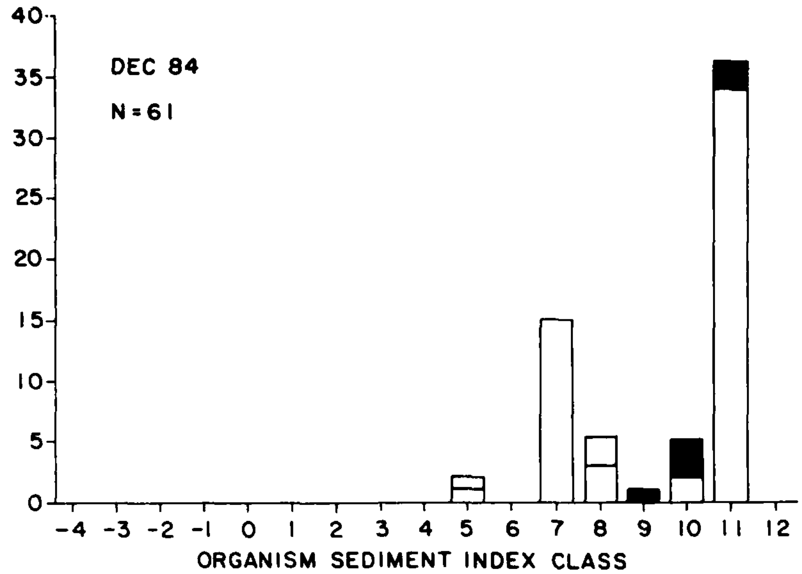


g. June 1984

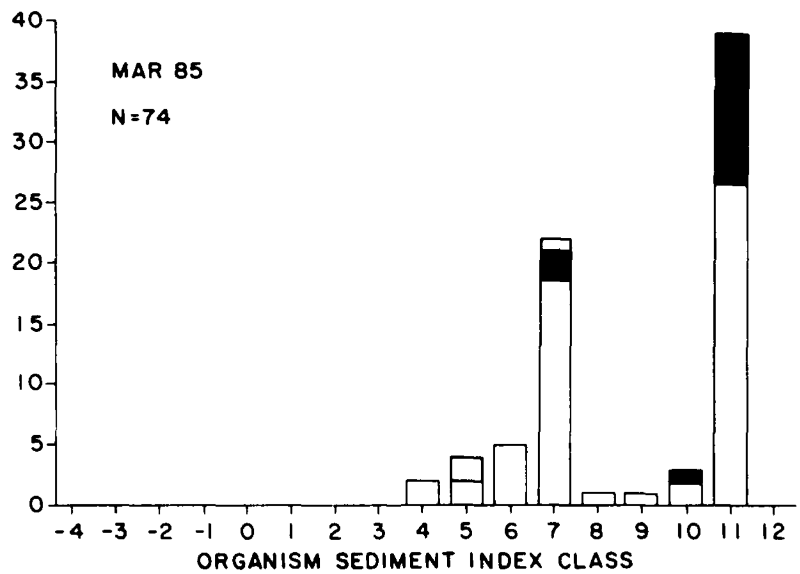


h. September 1984

Figure 28. (Sheet 4 of 6)

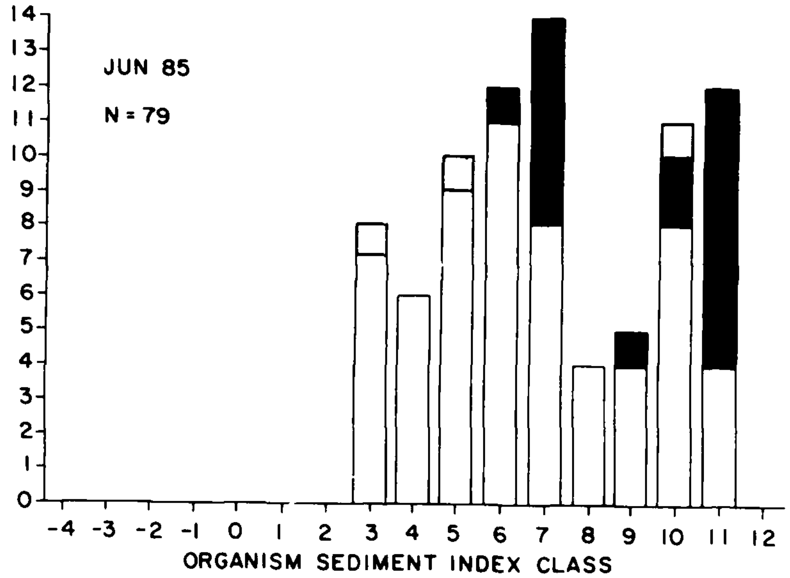


i. December 1984

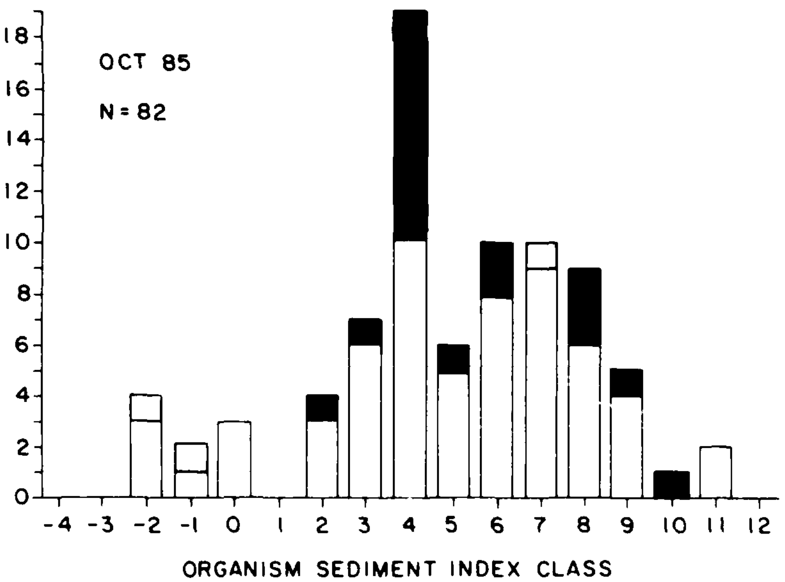


j. March 1985

Figure 28. (Sheet 5 of 6)



k. June 1985



l. October 1985

Figure 28. (Sheet 6 of 6)

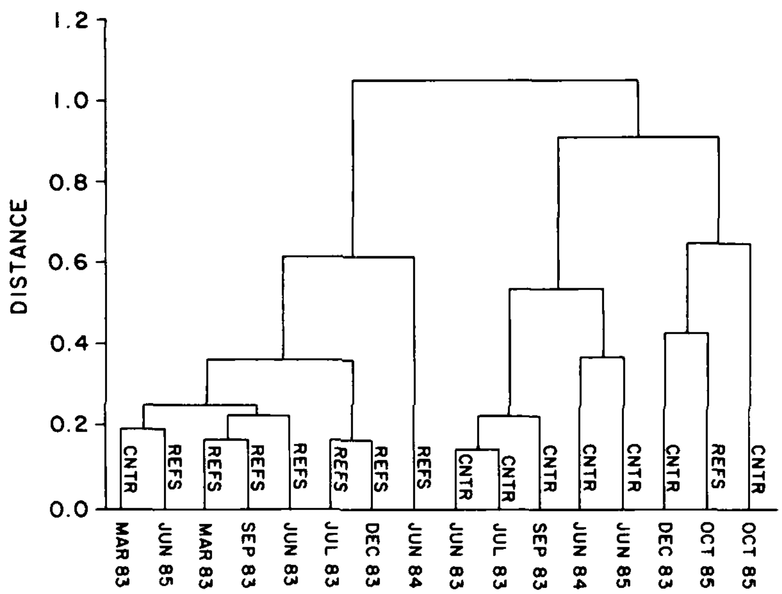
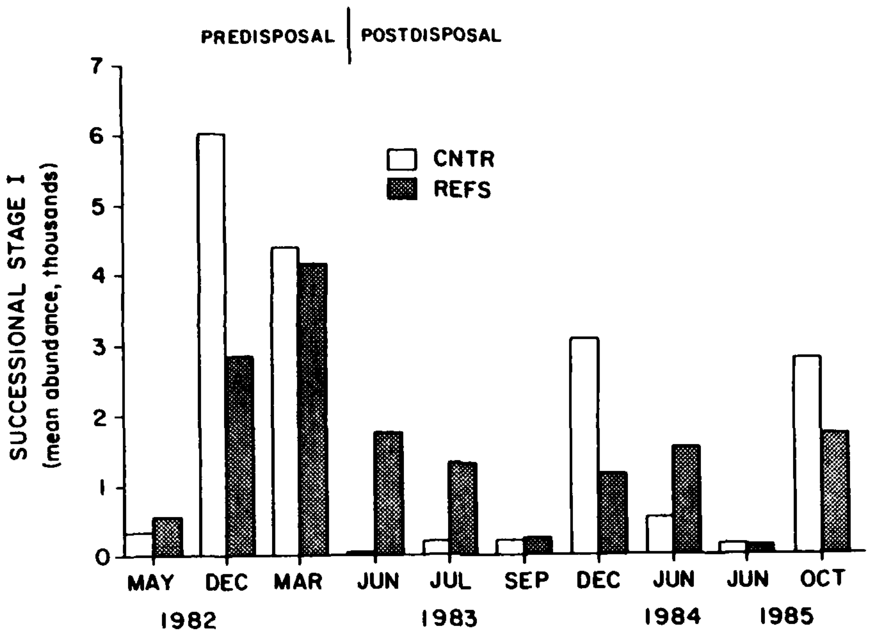
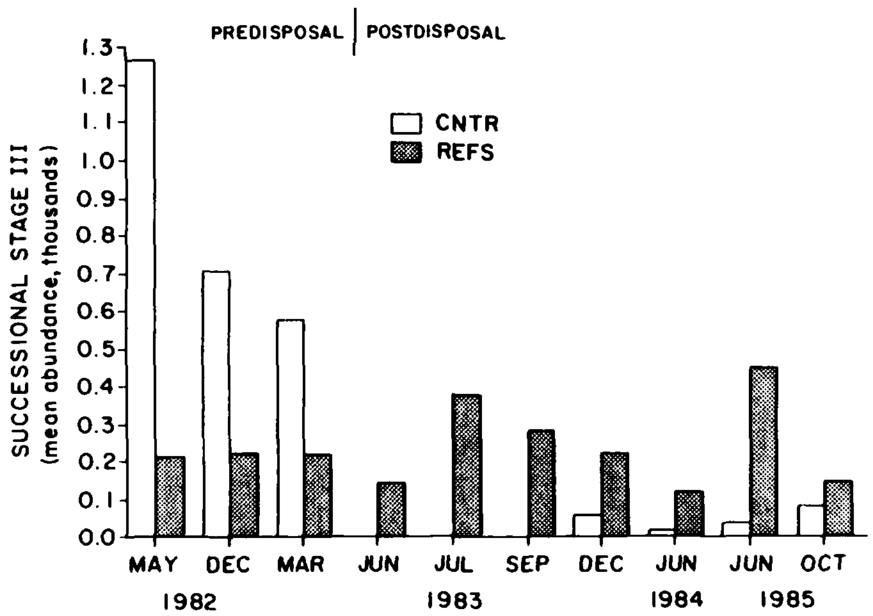


Figure 29. Hierarchical cluster analysis of BMD, OSI, mean number of species, and individuals per quadrat at CNTR and REFS from predisposal and postdisposal sampling dates



a. Successional Stage I



b. Successional Stage III

Figure 30. Mean abundances of Stage I and Stage III organisms at CNTR and REFS from May 1982 to October 1985

APPENDIX A: ALL SPECIES FOUND IN THE FVP BENTHIC INFAUNAL COMMUNITY ANALYSIS

Class	Species*
Annelid	*Archiannelid* sp.
Cnidaria	*Ceriantheopsis americanus*
	Corymorpha pendula
	Edwardsia elegans
	Haloclava producta
Crustacea	*Ampelisca* sp.
	Ampelisca vadorum **
	Axius serrata **
	Cancer irroratus
	Caprella sp.
	Corophium sp.
	Crangon septemspinosa
	Diastylis polita **
	Dyopedos monocantha
	Edotea montosa
	Gamarrus sp.
	Hutchinsoniella macracantha
	Leptocheiros pinguis **
	Libinia sp. **
	Microdeutopus gryllotalpa **
	Oxyurostylis smithi
	Pagurus longicarpus
	Parametopella cypris
	Pinnixia sp.
	Rhithropanopeus haraisii **
	Stenothoe minuta **
	Unciola irrorata
	Upogebia affinis **
Echinoderma	*Asterias forbesi*
Gastropoda	*Aceton punctostriatus*
	Crepidula spat **
	Cylichna oryza
	Epitonium rupicola
	Hydrobia sp.
	Lunatia heros
	Melanella intermedia
	Mitrella lunatia **
	Nassarius trivatatus
	Nudibranchia sp. **

* Number of species found all dates = 112.
** Found only postdisposal.

Class	Species*
Gastropoda (con't)	*Odostomia a* *Odostomia b* *Periploma papyratium* *Retusa canaliculata* *Retusa obtusa* *Turbonilla interrupta*
Hemichordata	*Saccoglossus kowalevskii*
Mollusca	*Anadara* sp.
Oligochaeta	*Oligochaeta* sp. *Peloscolex* sp.
Pelecypoda	*Aligena elevata* *Cerastraderma pinnulatum* ** *Ensis directus* ** *Lepton* sp. ** *Lyonsia hyalina* *Macoma tenta* *Mulinia lateralis* *Mytilus edulis* ** *Nucula annulata* *Pandora gouldiana* *Petricola pholadiformis* ** *Pitar morrhuana* *Tellina agilis* *Yoldia limatula*
Phoronida	*Phoronis muelleri*
Platyhelminthes	*Platyhelminthes*
Polychaeta	*Ampherite arctica* ** *Ampharete ornata* ** *Aricidea jeffreysii* *Asabellides oculata* *Asychis elongata* *Capitella capitata* ** *Chaetozone setosa* ** *Clymenella torquata* *Cossura longocirrata* *Driloneries longa* ** *Eteone heteropoda* *Glycera americana* *Harmothoe* sp. *Loimia medusa* **

* Number of species found all dates = 112.
** Found only postdisposal.

Class	Species*
Polychaeta (con't)	*Lumbrineris fragilis*
	Mediomastus ambiseta
	Melinna cristata
	Nephtys acta **
	Nephtys incisa
	Nereis succinea **
	Ninoe nigripes
	Owenia fusiformis **
	Paranaitis speciosa
	Paraonis gracilis
	Pectinaria gouldi
	Pherusa affinis
	Phloe minuta
	Phyllodoce arenae **
	Phylodoce sp. **
	Podarke obscura
	Polycirrus sp.
	Polydora caulleri
	Polydora ligni
	Polydora quadrilobata
	Polydora socialis **
	Prionospio steenstripi
	Sabellaria vulgaris **
	Sigambra tentaculata
	Spiochaetopterus oculatus **
	Spio filicornis
	Spiophanes bombyx **
	Streblospio benidicti
	Syllis gracillis
	Tharyx sp.
Rhynchocoela	*Cerebratulus lacteus*
	Rhynchocoela sp.
	Tubulanus pellucidus
Sipuncula	*Phascolion strombi*

* Number of species found all dates = 112.

** Found only postdisposal.

APPENDIX B: SPECIES MEAN ABUNDANCES

1. Mean density per 0.1 m^2 and standard deviation of the dominant species collected at the FVP site from May 1982 to October 1985. Dates are represented as year, month, day. Station locations are CNTR, REFS, and distance from CNTR in the north (N), south (S), east (E) and west (W) compass directions. The number of samples (N) used to calculate the mean is also shown.

SPECIES: *Nucula annulata*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	176.00000	84.53993	3
820504	100E	297.00000	0.00000	1
820504	100S	493.00000	0.00000	1
820504	100W	611.00000	0.00000	1
820504	150E	417.00000	0.00000	1
820504	150S	160.00000	0.00000	1
820504	150W	176.00000	0.00000	1
820504	200E	176.00000	0.00000	1
820504	200S	182.00000	0.00000	1
820504	200W	312.00000	0.00000	1
820504	250E	491.00000	0.00000	1
820504	250S	326.00000	0.00000	1
820504	250W	396.00000	0.00000	1
820504	300E	107.00000	0.00000	1
820504	300S	131.00000	0.00000	1
820504	300W	500.00000	0.00000	1
820504	350E	322.00000	0.00000	1
820504	350S	282.00000	0.00000	1
820504	350W	739.00000	0.00000	1
820504	400E	223.00000	0.00000	1
820504	400S	405.00000	0.00000	1
820504	400W	635.00000	0.00000	1
820504	450E	220.00000	0.00000	1
820504	450S	428.00000	0.00000	1
820504	450W	308.00000	0.00000	1
820504	500E	239.00000	0.00000	1
820504	500S	457.00000	0.00000	1
820504	500W	1491.00000	0.00000	1
820504	50E	330.00000	0.00000	1
820504	50S	518.00000	0.00000	1
820504	50W	509.00000	0.00000	1
820504	600E	249.00000	0.00000	1
820504	CNTR	1092.00000	0.00000	1
820504	REFS	232.33332	36.96398	3
820824	1000E	289.50000	131.66752	4
820824	100N	358.00000	0.00000	1
820824	150N	671.00000	0.00000	1
820824	200E	370.50000	93.68565	4
820824	200N	978.50000	130.98637	8
820824	250N	660.00000	0.00000	1
820824	300N	1008.00000	0.00000	1
820824	350N	829.00000	0.00000	1
820824	400E	542.25000	149.68940	4
820824	400N	546.00000	0.00000	1
820824	50N	928.00000	0.00000	1
820824	600E	408.50000	245.60877	4
820824	REFS	537.25000	194.17754	4
821208	1000E	230.39999	91.90102	5
821208	200E	364.39999	178.40067	5
821208	400E	443.20001	121.39482	5
821208	CNTR	495.20001	199.53869	5
821208	REFS	358.39999	110.71945	5
830315	1000E	532.40002	671.20811	5
830315	200E	554.79998	55.93467	5
830315	400E	386.20001	150.45499	5

(Continued)

Nucula annulata (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	443.60000	162.52169	5
830315	REFS	460.79998	121.09578	5
830603	1000E	368.79998	175.53548	5
830603	200E	252.00000	55.45268	5
830603	400E	375.79998	160.62754	5
830603	CNTR	2.20000	0.83665	5
830603	REFS	282.00000	72.86289	5
830714	1000E	513.20001	351.15340	5
830714	200E	239.00000	57.31056	5
830714	400E	555.40002	164.86756	5
830714	CNTR	0.40000	0.54772	5
830714	REFS	498.39999	273.73403	5
830906	1000E	313.20001	120.27761	5
830906	200E	232.39999	91.87653	5
830906	400E	551.20001	111.67223	5
830906	CNTR	0.80000	1.30384	5
830906	REFS	814.59997	232.15580	5
831201	1000E	384.20001	189.54473	5
831201	200E	113.00000	42.74342	5
831201	400E	181.80000	57.92408	5
831201	CNTR	19.79999	41.49940	5
831201	REFS	371.39999	175.67669	5
840612	CNTR	1.33333	1.15470	3
840612	REFS	648.33331	82.79078	3
850625	CNTR	1.00000	1.00000	3
850625	REFS	1272.33337	339.92980	3
851022	CNTR	2.00000	1.73205	3
851022	REFS	925.00000	36.16628	3

SPECIES: *Mediomastus ambiseta*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	8.66666	3.05505	3
820504	100E	7.00000	0.00000	1
820504	100S	17.00000	0.00000	1
820504	100W	0.00000	0.00000	1
820504	150E	8.00000	0.00000	1
820504	150S	6.00000	0.00000	1
820504	150W	13.00000	0.00000	1
820504	200E	0.00000	0.00000	1
820504	200S	2.00000	0.00000	1
820504	200W	0.00000	0.00000	1
820504	250E	0.00000	0.00000	1
820504	250S	4.00000	0.00000	1
820504	250W	9.00000	0.00000	1
820504	300E	4.00000	0.00000	1
820504	300S	2.00000	0.00000	1
820504	300W	15.00000	0.00000	1
820504	350E	6.00000	0.00000	1
820504	350S	3.00000	0.00000	1
820504	350W	27.00000	0.00000	1
820504	400E	1.00000	0.00000	1
820504	400S	2.00000	0.00000	1
820504	400W	26.00000	0.00000	1
820504	450E	11.00000	0.00000	1
820504	450S	4.00000	0.00000	1
820504	450W	1.00000	0.00000	1
820504	500E	10.00000	0.00000	1
820504	500S	5.00000	0.00000	1
820504	500W	6.00000	0.00000	1
820504	50E	4.00000	0.00000	1
820504	50S	5.00000	0.00000	1
820504	50W	7.00000	0.00000	1
820504	600E	33.00000	0.00000	1
820504	CNTR	13.00000	0.00000	1
820504	REFS	3.00000	4.35889	3
820824	1000E	314.75000	97.91961	4
820824	100N	73.00000	0.00000	1
820824	150N	365.00000	0.00000	1
820824	200E	236.75000	130.76794	4
820824	200N	129.87500	57.28983	8
820824	250N	228.00000	0.00000	1
820824	300N	37.00000	0.00000	1
820824	350N	49.00000	0.00000	1
820824	400E	163.50000	92.98208	4
820824	400N	52.00000	0.00000	1
820824	50N	316.00000	0.00000	1
820824	600E	139.25000	101.91622	4
820824	REFS	175.50000	164.24880	4
821208	1000E	6349.60009	1475.52170	5
821208	200E	5403.60009	2344.43965	5
821208	400E	6625.60009	2452.53608	5
821208	CNTR	4938.39990	2075.47944	5
821208	REFS	2465.39990	1715.86472	5
830315	1000E	5435.39990	1528.14145	5
830315	200E	4848.79980	1814.02048	5
830315	400E	5121.20019	1798.99765	5

(Continued)

Mediomastus ambiseta (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	4009.00000	2194.59907	5
830315	REFS	3915.60009	1027.54184	5
830603	1000E	4059.19995	834.91319	5
830603	200E	1637.59997	944.93535	5
830603	400E	2632.19995	432.05788	5
830603	CNTR	39.59999	28.27189	5
830603	REFS	1601.80004	1219.51059	5
830714	1000E	2307.00000	820.39903	5
830714	200E	246.80000	138.17997	5
830714	400E	1865.59997	894.31737	5
830714	CNTR	9.80000	6.09918	5
830714	REFS	1161.80004	874.33110	5
830906	1000E	402.20001	206.23217	5
830906	200E	165.00000	21.42428	5
830906	400E	211.00000	60.07079	5
830906	CNTR	11.00000	11.66190	5
830906	REFS	94.19999	30.97903	5
831201	1000E	1918.00000	644.22557	5
831201	200E	751.40002	763.50926	5
831201	400E	1776.19995	618.96855	5
831201	CNTR	392.60000	350.70830	5
831201	REFS	533.20001	189.36127	5
840612	CNTR	303.66665	495.66152	3
840612	REFS	1188.00000	631.35417	3
850625	CNTR	132.33332	119.45850	3
850625	REFS	107.66666	30.66486	3
851022	CNTR	2361.00000	1694.82443	3
851022	REFS	1181.33337	404.81154	3

SPECIES: *Mulinia lateralis*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	130.33332	65.16390	3
820504	100E	183.00000	0.00000	1
820504	100S	359.00000	0.00000	1
820504	100W	187.00000	0.00000	1
820504	150E	400.00000	0.00000	1
820504	150S	178.00000	0.00000	1
820504	150W	90.00000	0.00000	1
820504	200E	154.00000	0.00000	1
820504	200S	75.00000	0.00000	1
820504	200W	165.00000	0.00000	1
820504	250E	330.00000	0.00000	1
820504	250S	567.00000	0.00000	1
820504	250W	89.00000	0.00000	1
820504	300E	43.00000	0.00000	1
820504	300S	127.00000	0.00000	1
820504	300W	77.00000	0.00000	1
820504	350E	193.00000	0.00000	1
820504	350S	261.00000	0.00000	1
820504	350W	232.00000	0.00000	1
820504	400E	98.00000	0.00000	1
820504	400S	191.00000	0.00000	1
820504	400W	238.00000	0.00000	1
820504	450E	168.00000	0.00000	1
820504	450S	307.00000	0.00000	1
820504	450W	66.00000	0.00000	1
820504	500E	193.00000	0.00000	1
820504	500S	456.00000	0.00000	1
820504	500W	226.00000	0.00000	1
820504	50E	221.00000	0.00000	1
820504	50S	299.00000	0.00000	1
820504	50W	252.00000	0.00000	1
820504	600E	254.00000	0.00000	1
820504	CNTR	322.00000	0.00000	1
820504	REFS	524.33331	168.62191	3
820824	1000E	6.50000	4.20317	4
820824	100N	0.00000	0.00000	1
820824	150N	1.00000	0.00000	1
820824	200E	3.25000	2.50000	4
820824	200N	3.25000	2.18762	8
820824	250N	12.00000	0.00000	1
820824	300N	0.00000	0.00000	1
820824	350N	0.00000	0.00000	1
820824	400E	0.00000	0.00000	4
820824	400N	2.00000	0.00000	1
820824	50N	4.00000	0.00000	1
820824	600E	1.25000	1.25830	4
820824	REFS	144.25000	33.98406	4
821208	1000E	901.40002	208.10876	5
821208	200E	831.59997	287.97365	5
821208	400E	1239.00000	250.31281	5
821208	CNTR	1076.40002	169.66512	5
821208	REFS	369.60000	289.73143	5
830315	1000E	672.40002	278.74059	5
830315	200E	371.60000	215.63697	5
830315	400E	607.59997	182.03384	5

(Continued)

Mulinia lateralis (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	359.60000	178.94915	5
830315	REFS	221.60000	107.00140	5
830603	1000E	378.20001	126.66374	5
830603	200E	126.19999	86.82856	5
830603	400E	407.00000	198.27129	5
830603	CNTR	1.00000	1.41421	5
830603	REFS	146.19999	125.87772	5
830714	1000E	358.00000	98.32345	5
830714	200E	54.20000	13.91761	5
830714	400E	347.00000	94.49868	5
830714	CNTR	0.20000	0.44721	5
830714	REFS	141.00000	124.45883	5
830906	1000E	134.60000	46.09014	5
830906	200E	8.80000	1.30383	5
830906	400E	127.80000	30.40886	5
830906	CNTR	0.20000	0.44721	5
830906	REFS	138.19999	71.36665	5
831201	1000E	1136.19995	440.05813	5
831201	200E	744.20001	319.55001	5
831201	400E	1232.00000	290.92354	5
831201	CNTR	2177.00000	774.00200	5
831201	REFS	617.00000	295.68819	5
840612	CNTR	26.66666	27.79088	3
840612	REFS	280.00000	39.94997	3
850625	CNTR	5.33333	3.21455	3
850625	REFS	14.00000	4.35889	3
851022	CNTR	342.33334	95.26977	3
851022	REFS	517.33331	83.79942	3

SPECIES: *Oligochaeta* sp.

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	5.66666	4.93288	3
820504	100E	6.00000	0.00000	1
820504	100S	16.00000	0.00000	1
820504	100W	0.00000	0.00000	1
820504	150E	27.00000	0.00000	1
820504	150S	5.00000	0.00000	1
820504	150W	9.00000	0.00000	1
820504	200E	11.00000	0.00000	1
820504	200S	0.00000	0.00000	1
820504	200W	7.00000	0.00000	1
820504	250E	8.00000	0.00000	1
820504	250S	8.00000	0.00000	1
820504	250W	6.00000	0.00000	1
820504	300E	8.00000	0.00000	1
820504	300S	9.00000	0.00000	1
820504	300W	10.00000	0.00000	1
820504	350E	8.00000	0.00000	1
820504	350S	0.00000	0.00000	1
820504	350W	16.00000	0.00000	1
820504	400E	8.00000	0.00000	1
820504	400S	2.00000	0.00000	1
820504	40CW	33.00000	0.00000	1
820504	450E	14.00000	0.00000	1
820504	450S	26.00000	0.00000	1
820504	450W	11.00000	0.00000	1
820504	500E	1.00000	0.00000	1
820504	500S	15.00000	0.00000	1
820504	500W	11.00000	0.00000	1
820504	50E	3.00000	0.00000	1
820504	50S	18.00000	0.00000	1
820504	50W	8.00000	0.00000	1
820504	600E	16.00000	0.00000	1
820504	CNTR	12.00000	0.00000	1
820504	REFS	3.00000	4.35889	3
820824	1000E	22.50000	17.54043	4
820824	100N	9.00000	0.00000	1
820824	150N	35.00000	0.00000	1
820824	200E	15.50000	9.98332	4
820824	200N	23.75000	5.41822	8
820824	250N	17.00000	0.00000	1
820824	300N	7.00000	0.00000	1
820824	350N	8.00000	0.00000	1
820824	400E	18.75000	11.11680	4
820824	400N	11.00000	0.00000	1
820824	50N	36.00000	0.00000	1
820824	600E	16.00000	18.22086	4
820824	REFS	6.50000	1.91485	4
821208	1000E	75.00000	35.36948	5
821208	200E	53.40000	14.25833	5
821208	400E	127.80000	65.08225	5
821208	CNTR	67.00000	35.73514	5
821208	REFS	21.39999	15.04327	5
830315	1000E	124.80000	30.20263	5
830315	200E	97.40000	51.25719	5
830315	400E	81.80000	26.37613	5

(Continued)

Oligochaeta sp. (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	72.19999	26.01346	5
830315	REFS	59.00000	57.07013	5
830603	1000E	66.40000	100.54253	5
830603	200E	87.40000	32.20714	5
830603	400E	97.40000	50.74741	5
830603	CNTR	2.79999	2.38746	5
830603	REFS	24.20000	23.57329	5
830714	1000E	115.19999	105.23164	5
830714	200E	76.19999	17.83816	5
830714	400E	144.00000	70.01071	5
830714	CNTR	0.60000	0.54772	5
830714	REFS	48.79999	14.49827	5
830906	1000E	69.59999	39.98499	5
830906	200E	140.60000	33.93819	5
830906	400E	91.19999	30.06160	5
830906	CNTR	1.79999	3.49285	5
830906	REFS	39.59999	15.37205	5
831201	1000E	210.00000	88.20431	5
831201	200E	78.19999	63.67653	5
831201	400E	242.19999	50.43514	5
831201	CNTR	7.40000	14.36314	5
831201	REFS	110.59999	64.29074	5
840612	CNTR	11.33333	9.50438	3
840612	REFS	200.66667	45.79664	3
850625	CNTR	39.33333	6.42909	3
850625	REFS	280.33334	37.31402	3
851022	CNTR	27.33333	8.50490	3
851022	REFS	98.66666	76.27145	3

SPECIES: *Nephtys incisa*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	106.66666	11.37251	3
820504	100E	141.00000	0.00000	1
820504	100S	118.00000	0.00000	1
820504	100W	118.00000	0.00000	1
820504	150E	127.00000	0.00000	1
820504	150S	149.00000	0.00000	1
820504	150W	137.00000	0.00000	1
820504	200E	88.00000	0.00000	1
820504	200S	59.00000	0.00000	1
820504	200W	85.00000	0.00000	1
820504	250E	123.00000	0.00000	1
820504	250S	99.00000	0.00000	1
820504	250W	135.00000	0.00000	1
820504	300E	74.00000	0.00000	1
820504	300S	125.00000	0.00000	1
820504	300W	113.00000	0.00000	1
820504	350E	114.00000	0.00000	1
820504	350S	169.00000	0.00000	1
820504	350W	119.00000	0.00000	1
820504	400E	74.00000	0.00000	1
820504	400S	141.00000	0.00000	1
820504	400W	85.00000	0.00000	1
820504	450E	96.00000	0.00000	1
820504	450S	161.00000	0.00000	1
820504	450W	52.00000	0.00000	1
820504	500E	142.00000	0.00000	1
820504	500S	109.00000	0.00000	1
820504	500W	161.00000	0.00000	1
820504	50E	129.00000	0.00000	1
820504	50S	135.00000	0.00000	1
820504	50W	148.00000	0.00000	1
820504	600E	104.00000	0.00000	1
820504	CNTR	146.00000	0.00000	1
820504	REFS	160.33333	27.75486	3
820824	1000E	76.33990	10.08138	4
820824	100N	83.18417	0.00000	1
820824	150N	106.34937	0.00000	1
820824	200E	80.02528	8.20136	4
820824	200N	74.89207	8.12582	8
820824	250N	95.81973	0.00000	1
820824	300N	92.66084	0.00000	1
820824	350N	95.81973	0.00000	1
820824	400E	71.86480	27.99612	4
820824	400N	73.70749	0.00000	1
820824	50N	106.34937	0.00000	1
820824	600E	54.75414	39.68809	4
820824	REFS	93.45056	19.72496	4
821208	1000E	53.80000	9.01111	5
821208	200E	54.60000	7.82944	5
821208	400E	53.60000	7.33485	5
821208	CNTR	55.40000	14.74110	5
821208	REFS	48.60000	6.38749	5
830315	1000E	44.60000	8.14249	5

(Continued)

Nephtys incisa (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	200E	42.80000	26.45184	5
830315	400E	45.20000	6.01664	5
830315	CNTR	41.40000	5.81378	5
830315	REFS	47.00000	6.78233	5
830603	1000E	33.06307	16.64216	5
830603	200E	33.27367	11.90362	5
830603	400E	40.64442	3.12363	5
830603	CNTR	0.21059	0.47090	5
830603	REFS	37.48552	14.42984	5
830714	1000E	44.43509	24.64251	5
830714	200E	20.84869	4.73249	5
830714	400E	32.85248	7.53439	5
830714	CNTR	0.63178	0.57673	5
830714	REFS	37.69611	4.79071	5
830906	1000E	29.90418	2.64294	5
830906	200E	22.11225	2.46942	5
830906	400E	27.37707	4.34149	5
830906	CNTR	1.68474	2.64292	5
830906	REFS	30.53596	7.98451	5
831201	1000E	17.68980	3.67785	5
831201	200E	15.79446	3.41200	5
831201	400E	18.53217	2.05259	5
831201	CNTR	14.74150	14.87254	5
831201	REFS	13.89913	7.34815	5
840612	CNTR	3.50988	2.43172	3
840612	REFS	17.54940	3.21685	3
850625	CNTR	15.09249	4.25550	3
850625	REFS	22.11225	4.82528	3
851022	CNTR	67.03872	16.11870	3
851022	REFS	54.40315	8.76767	3

SPECIES: *Yoldia limatula*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	40.33333	14.97775	3
820504	100E	23.00000	0.00000	1
820504	100S	32.00000	0.00000	1
820504	100W	45.00000	0.00000	1
820504	150E	24.00000	0.00000	1
820504	150S	33.00000	0.00000	1
820504	150W	30.00000	0.00000	1
820504	200E	17.00000	0.00000	1
820504	200S	10.00000	0.00000	1
820504	200W	33.00000	0.00000	1
820504	250E	29.00000	0.00000	1
820504	250S	23.00000	0.00000	1
820504	250W	55.00000	0.00000	1
820504	300E	4.00000	0.00000	1
820504	300S	15.00000	0.00000	1
820504	300W	69.00000	0.00000	1
820504	350E	50.00000	0.00000	1
820504	350S	22.00000	0.00000	1
820504	350W	53.00000	0.00000	1
820504	400E	15.00000	0.00000	1
820504	400S	28.00000	0.00000	1
820504	400W	55.00000	0.00000	1
820504	450E	22.00000	0.00000	1
820504	450S	36.00000	0.00000	1
820504	450W	21.00000	0.00000	1
820504	500E	30.00000	0.00000	1
820504	500S	49.00000	0.00000	1
820504	500W	35.00000	0.00000	1
820504	50E	27.00000	0.00000	1
820504	50S	27.00000	0.00000	1
820504	50W	12.00000	0.00000	1
820504	600E	39.00000	0.00000	1
820504	CNTR	29.00000	0.00000	1
820504	REFS	18.33333	11.84623	3
820824	1000E	7.75000	2.21735	4
820824	100N	7.00000	0.00000	1
820824	150N	9.00000	0.00000	1
820824	200E	10.00000	3.91578	4
820824	200N	21.62500	6.69621	8
820824	250N	12.00000	0.00000	1
820824	300N	6.00000	0.00000	1
820824	350N	11.00000	0.00000	1
820824	400E	6.50000	2.38047	4
820824	400N	11.00000	0.00000	1
820824	50N	11.00000	0.00000	1
820824	600E	6.50000	3.10912	4
820824	REFS	8.75000	1.70782	4
821208	1000E	111.80000	28.65659	5
821208	200E	147.19999	44.11575	5
821208	400E	124.80000	59.58355	5
821208	CNTR	155.39999	29.75400	5
821208	REFS	61.20000	28.44644	5
830315	1000E	135.60000	42.34147	5
830315	200E	111.40000	33.82750	5
830315	400E	140.80000	17.23946	5

(Continued)

Yoldia limatula (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	91.40000	54.03054	5
830315	REFS	51.59999	10.92245	5
830603	1000E	91.80000	27.04071	5
830603	200E	40.79999	17.02057	5
830603	400E	60.20000	23.86839	5
830603	CNTR	0.00000	0.00000	5
830603	REFS	34.00000	13.94632	5
830714	1000E	115.80000	47.12429	5
830714	200E	25.79999	3.96232	5
830714	400E	82.00000	11.33578	5
830714	CNTR	1.20000	1.64316	5
830714	REFS	66.19999	13.84558	5
830906	1000E	12.80000	8.75785	5
830906	200E	1.20000	0.83666	5
830906	400E	3.40000	2.70185	5
830906	CNTR	0.00000	0.00000	5
830906	REFS	16.00000	6.28490	5
831201	1000E	29.79999	13.55359	5
831201	200E	16.79999	9.17605	5
831201	400E	17.39999	3.97491	5
831201	CNTR	19.20000	27.79748	5
831201	REFS	31.00000	21.76005	5
840612	CNTR	4.00000	5.29150	3
840612	REFS	16.33333	4.04145	3
850625	CNTR	14.33333	7.63762	3
850625	REFS	84.00000	15.39480	3
851022	CNTR	13.33333	13.57694	3
851022	REFS	52.66666	20.74448	3

SPECIES: *Polydora ligni*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	0.00000	0.00000	3
820504	100E	0.00000	0.00000	1
820504	100S	0.00000	0.00000	1
820504	100W	0.00000	0.00000	1
820504	150E	0.00000	0.00000	1
820504	150S	0.00000	0.00000	1
820504	150W	0.00000	0.00000	1
820504	200E	0.00000	0.00000	1
820504	200S	0.00000	0.00000	1
820504	200W	0.00000	0.00000	1
820504	250E	0.00000	0.00000	1
820504	250S	0.00000	0.00000	1
820504	250W	0.00000	0.00000	1
820504	300E	0.00000	0.00000	1
820504	300S	0.00000	0.00000	1
820504	300W	0.00000	0.00000	1
820504	350E	0.00000	0.00000	1
820504	350S	0.00000	0.00000	1
820504	350W	0.00000	0.00000	1
820504	400E	0.00000	0.00000	1
820504	400S	0.00000	0.00000	1
820504	400W	0.00000	0.00000	1
820504	450E	0.00000	0.00000	1
820504	450S	0.00000	0.00000	1
820504	450W	0.00000	0.00000	1
820504	500E	0.00000	0.00000	1
820504	500S	0.00000	0.00000	1
820504	500W	0.00000	0.00000	1
820504	50E	0.00000	0.00000	1
820504	50S	0.00000	0.00000	1
820504	50W	0.00000	0.00000	1
820504	600E	0.00000	0.00000	1
820504	CNTR	0.00000	0.00000	1
820504	REFS	0.00000	0.00000	3
820824	1000E	0.00000	0.00000	4
820824	100N	0.00000	0.00000	1
820824	150N	0.00000	0.00000	1
820824	200E	0.00000	0.00000	4
820824	200N	0.00000	0.00000	8
820824	250N	0.00000	0.00000	1
820824	300N	0.00000	0.00000	1
820824	350N	0.00000	0.00000	1
820824	400E	0.00000	0.00000	4
820824	400N	0.00000	0.00000	1
820824	50N	0.00000	0.00000	1
820824	600E	0.00000	0.00000	4
820824	REFS	0.00000	0.00000	4
821208	1000E	0.00000	0.00000	5
821208	200E	0.20000	0.44721	5
821208	400E	0.40000	0.89442	5
821208	CNTR	0.00000	0.00000	5
821208	REFS	0.20000	0.44721	5
830315	1000E	0.00000	0.00000	5
830315	200E	0.00000	0.00000	5
830315	400E	0.00000	0.00000	5

(Continued)

Polydora ligni (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	0.00000	0.00000	5
830315	REFS	0.00000	0.00000	5
830603	1000E	0.00000	0.00000	5
830603	200E	0.00000	0.00000	5
830603	400E	0.00000	0.00000	5
830603	CNTR	2.00000	3.39116	5
830603	REFS	0.00000	0.00000	5
830714	1000E	1.60000	1.51657	5
830714	200E	54.40000	19.38556	5
830714	400E	3.00000	1.87082	5
830714	CNTR	192.39999	110.80298	5
830714	REFS	0.40000	0.54772	5
830906	1000E	0.00000	0.00000	5
830906	200E	0.00000	0.00000	5
830906	400E	0.00000	0.00000	5
830906	CNTR	4.80000	4.91935	5
830906	REFS	0.20000	0.44721	5
831201	1000E	41.59999	14.55335	5
831201	200E	6.19999	5.58569	5
831201	400E	2.40000	3.04959	5
831201	CNTR	143.80000	181.06547	5
831201	REFS	0.80000	1.78885	5
840612	CNTR	89.33333	41.86088	3
840612	REFS	0.00000	0.00000	3
850625	CNTR	0.00000	0.00000	3
850625	REFS	0.00000	0.00000	3
851022	CNTR	60.33333	65.20992	3
851022	REFS	1.00000	1.00000	3

SPECIES: *Streblospio benedicti*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	0.00000	0.00000	3
820504	100E	0.00000	0.00000	1
820504	100S	0.00000	0.00000	1
820504	100W	0.00000	0.00000	1
820504	150E	0.00000	0.00000	1
820504	150S	0.00000	0.00000	1
820504	150W	0.00000	0.00000	1
820504	200E	0.00000	0.00000	1
820504	200S	0.00000	0.00000	1
820504	200W	0.00000	0.00000	1
820504	250E	0.00000	0.00000	1
820504	250S	0.00000	0.00000	1
820504	250W	0.00000	0.00000	1
820504	300E	0.00000	0.00000	1
820504	300S	0.00000	0.00000	1
820504	300W	0.00000	0.00000	1
820504	350E	0.00000	0.00000	1
820504	350S	0.00000	0.00000	1
820504	350W	0.00000	0.00000	1
820504	400E	0.00000	0.00000	1
820504	400S	0.00000	0.00000	1
820504	400W	0.00000	0.00000	1
820504	450E	0.00000	0.00000	1
820504	450S	1.00000	0.00000	1
820504	450W	0.00000	0.00000	1
820504	500E	0.00000	0.00000	1
820504	500S	0.00000	0.00000	1
820504	500W	1.00000	0.00000	1
820504	50E	0.00000	0.00000	1
820504	50S	0.00000	0.00000	1
820504	50W	0.00000	0.00000	1
820504	600E	0.00000	0.00000	1
820504	CNTR	0.00000	0.00000	1
820504	REFS	0.00000	0.00000	3
820824	1000E	0.00000	0.00000	4
820824	100N	0.00000	0.00000	1
820824	150N	0.00000	0.00000	1
820824	200E	0.00000	0.00000	4
820824	200N	0.00000	0.00000	8
820824	250N	0.00000	0.00000	1
820824	300N	0.00000	0.00000	1
820824	350N	0.00000	0.00000	1
820824	400E	0.00000	0.00000	4
820824	400N	0.00000	0.00000	1
820824	50N	0.00000	0.00000	1
820824	600E	0.00000	0.00000	4
820824	REFS	0.00000	0.00000	4
821208	1000E	9.80000	6.72309	5
821208	200E	20.60000	15.56598	5
821208	400E	19.79999	12.73577	5
821208	CNTR	11.60000	3.57770	5
821208	REFS	3.79999	2.38746	5
830315	1000E	14.60000	9.86407	5
830315	200E	12.39999	11.08151	5
830315	400E	11.39999	6.10737	5

(Continued)

Streblospio benedicti (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	23.60000	10.83051	5
830315	REFS	6.19999	8.01249	5
830603	1000E	6.40000	4.39317	5
830603	200E	7.59999	2.70185	5
830603	400E	6.80000	4.65832	5
830603	CNTR	0.00000	0.00000	5
830603	REFS	8.19999	7.36206	5
830714	1000E	5.19999	3.11448	5
830714	200E	1.20000	2.16794	5
830714	400E	5.19999	1.92353	5
830714	CNTR	1.20000	1.64316	5
830714	REFS	5.19999	6.09918	5
830906	1000E	14.39999	8.08084	5
830906	200E	162.80000	51.70299	5
830906	400E	40.40000	16.31870	5
830906	CNTR	178.39999	95.32209	5
830906	REFS	3.20000	1.92353	5
831201	1000E	64.40000	39.25939	5
831201	200E	76.59999	44.39932	5
831201	400E	55.20000	15.38505	5
831201	CNTR	369.60000	125.31280	5
831201	REFS	23.39999	15.59807	5
840612	CNTR	88.33333	68.97342	3
840612	REFS	43.00000	10.14889	3
850625	CNTR	1.00000	1.00000	3
850625	REFS	0.33333	0.57735	3
851022	CNTR	0.33333	0.57735	3
851022	REFS	0.00000	0.00000	3

SPECIES: *Tellina agilis*

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
820504	1000E	0.00000	0.00000	3
820504	100E	0.00000	0.00000	1
820504	100S	0.00000	0.00000	1
820504	100W	0.00000	0.00000	1
820504	150E	0.00000	0.00000	1
820504	150S	0.00000	0.00000	1
820504	150W	0.00000	0.00000	1
820504	200E	0.00000	0.00000	1
820504	200S	0.00000	0.00000	1
820504	200W	0.00000	0.00000	1
820504	250E	0.00000	0.00000	1
820504	250S	0.00000	0.00000	1
820504	250W	0.00000	0.00000	1
820504	300E	0.00000	0.00000	1
820504	300S	0.00000	0.00000	1
820504	300W	0.00000	0.00000	1
820504	350E	0.00000	0.00000	1
820504	350S	0.00000	0.00000	1
820504	350W	0.00000	0.00000	1
820504	400E	0.00000	0.00000	1
820504	400S	0.00000	0.00000	1
820504	400W	0.00000	0.00000	1
820504	450E	0.00000	0.00000	1
820504	450S	0.00000	0.00000	1
820504	450W	0.00000	0.00000	1
820504	500E	0.00000	0.00000	1
820504	500S	0.00000	0.00000	1
820504	500W	0.00000	0.00000	1
820504	50E	0.00000	0.00000	1
820504	50S	1.00000	0.00000	1
820504	50W	0.00000	0.00000	1
820504	600E	0.00000	0.00000	1
820504	CNTR	0.00000	0.00000	1
820504	REFS	0.00000	0.00000	3
820824	1000E	0.25000	0.50000	4
820824	100N	0.00000	0.00000	1
820824	150N	0.00000	0.00000	1
820824	200E	0.00000	0.00000	4
820824	200N	0.12500	0.35355	8
820824	250N	1.00000	0.00000	1
820824	300N	0.00000	0.00000	1
820824	350N	0.00000	0.00000	1
820824	400E	0.00000	0.00000	4
820824	400N	0.00000	0.00000	1
820824	50N	0.00000	0.00000	1
820824	600E	0.00000	0.00000	4
820824	REFS	0.00000	0.00000	4
821208	1000E	0.20000	0.44721	5
821208	200E	3.40000	7.60263	5
821208	400E	0.20000	0.44721	5
821208	CNTR	3.59999	7.50333	5
821208	REFS	0.00000	0.00000	5
830315	1000E	0.40000	0.89442	5
830315	200E	4.80000	4.60434	5
830315	400E	2.20000	2.28035	5

(Continued)

Tellina agilis (Concluded)

DATE	STATION	MEAN DENSITY	STANDARD DEVIATION	N
830315	CNTR	1.39999	1.67332	5
830315	REFS	1.79999	1.78885	5
830603	1000E	1.79999	1.48323	5
830603	200E	0.20000	0.44721	5
830603	400E	0.40000	0.89442	5
830603	CNTR	0.20000	0.44721	5
830603	REFS	0.00000	0.00000	5
830714	1000E	0.00000	0.00000	5
830714	200E	0.60000	0.89442	5
830714	400E	0.00000	0.00000	5
830714	CNTR	0.00000	0.00000	5
830714	REFS	0.20000	0.44721	5
830906	1000E	0.20000	0.44721	5
830906	200E	0.00000	0.00000	5
830906	400E	0.20000	0.44721	5
830906	CNTR	0.00000	0.00000	5
830906	REFS	0.00000	0.00000	5
831201	1000E	74.80000	55.34167	5
831201	200E	73.40000	43.46607	5
831201	400E	48.00000	10.36822	5
831201	CNTR	52.00000	71.23553	5
831201	REFS	14.00000	6.04152	5
840612	CNTR	1.33333	1.52752	3
840612	REFS	3.33333	2.08166	3
850625	CNTR	0.00000	0.00000	3
850625	REFS	0.33333	0.57735	3
851022	CNTR	240.33332	158.24772	3
851022	REFS	52.33333	19.13984	3

END

10-87

DTIC